AD 337 255 L

S & T MEMO 13/62

CONFIDENTIAL

INVESTIGATION OF THE HEAT RESISTANCE OF AIRCRAFT TYRES AND COMPONENT MATERIALS [U]

Report Of Work Carried Out By Dunlop Rubber Co.Ltd.
Under Ministry of Aviation Contract No.6/Stores/38161/C.B.20(a).

ISSUED

FEBRUARY, 1963

By

Technical Information and Library Services

Ministry of Aviation

629.13.015.125:
678.074: 66.018.4:
620.193.5

S & T Memo 13/62

CONFIDENTIAL

This report was prepared by the Dunlop Rubber Co.Ltd., under contract No.6/Stores/38161/CB.20(a) for the M.O.A., who accept no responsibility for the opinions expressed by the authors. Any comments arising from this report should be addressed to M.O.A. and not to Dunlop Rubber Co.Ltd.

INVESTIGATION OF THE HEAT RESISTANCE OF AIRCRAFT TYRES AND COMPONENT MATERIALS.

Report prepared by

G.B. Roberts, B.Sc.

of

THE DUNLOP RUBBER COMPANY LIMITED.

SUMMARY.

This third S. & T. Memo records further work done in connection with laboratory investigation of materials and the behaviour of tyres under high temperature conditions.

Further tyre heating tests have been carried out, using the infra red heating chamber, to confirm and extend the results from earlier work on standard construction tyres and to show the effect of lining the chamber with heat insulating materials.

Some work has been done on cooling pre-heated tyres in wind tunnels over a range of wind speeds.

Work has continued on the production of steel casing tyres to new constructions and using heat resistant polymers.

CONFIDENTIAL

List of Contents

List of Contents.

List of Contents.

List of Illustrations.

List of Tables.

PART I.

INVESTIGATION OF MATERIALS

1. Introduction.

This part of the memorandum describes further laboratory tests to determine how the properties of the component parts of tyres are affected by heat. The emphasis has been on evaluating the properties of the newer synthetic polymers from the points of view of processing and heat degradation.

The actual figures given in the co-ordinates of the appended graphs represent the average properties of the components in use at, produced by, or evaluated by Dunlop.

Where tests at high temperatures are reported these were carried out on the modified Hounsfield Tensile Machine, described in S. & T.M. 15/57.

Tests on nylon cords are also reviewed.

1.1. Laboratory Evaluation of Heat Resistant Elastomers, and Tyre Cords.

Laboratory tensile tests have been carried out on samples of various elastomers (obtained from the respective manufacturers in an uncured state) after processing and curing.

The tensile test was chosen for evaluation of the small quantities available, since it is considered that changes in tensile strength and elongation give a reliable indication of the amount of degradation induced by heating cycles.

In the case of butyl rubbers, which show promise as material for a heat resistant tyre, additional tests were performed to measure tear resistance and adhesion to steel wire.

1.1.1. Silicone Rubbers

Past studies led to the rejection of silicone rubbers as tyre tread material for the major reasons of poor physical properties and extremely low abrasion resistance.

Since that time improvements in these rubbers have been effected and tests have been carried out on the new materials to determine the possibility of combining silicone and glass fibre to form a flexible heat insulating material for inner tube protection.

1.1.1.1. Silicone E.303

Supplied by Messrs. I.C.I. Ltd., this material was found very difficult to process and no suitable test specimens were produced.

1.1.1.2. Silicone D.P.2452.

Supplied by Midland Silicones Ltd., this silicone was found to be easy to process.

When reinforced with glass fibre the resulting material was too dense and brittle to be of any use as a flexible heat insulating layer.

Discussion.

No further consideration was given to the use of silicone rubbers either as tyre tread material or in heat insulating layers.

1.1.2. Polyurethane Elastomers.

1.1.2.1. Genthane S.

Made by General Tire & Rubber Co. of U.S.A.

It was reported in S. & T.M.18/59, para.1.2.2.2., that difficulty had been experienced in processing this material and that no suitable test specimen had been produced. Since then the material has been satisfactorily processed and samples have been heat aged and tested.

Ageing was carried out for 5 minutes, ½, 1, 2 and 4 hours at temperatures between 100°C and 175°C. Tensile tests were carried out at the ageing temperatures.

Tensile strength fell from its initial value of 3590 p.s.i. to less than one third of this after 5 minutes at 100°C and the material was not serviceable at temperatures above 150°C. See Fig.1.

No further consideration was given to this material as it is clearly of no practical use at temperatures above 150°C.

1.1.3. Fluoro Elastomers.

1.1.3.1. Viton A.

This is a copolymer of vinylidine fluoride and hexafluoropropylene made by Du Pont de Nemours, U.S.A.

It was reported in S. & T.M. 18/59, para.1.2.3.1., that porosity had rendered test specimens unsuitable. This fault has now been overcome to some extent and suitable test specimens have been produced, heat aged and tested.

Compound 1

Incorporated a medium thermal black.

Test specimens were aged for 5 minutes ½, 1, 2 and 4 hours at 200°C and tested at that temperature. Tensile strength fell from 2,020 p.s.i. initially to about 350 p.s.i. after each of the ageing periods. Further test pieces were aged for 4 hours at 200°C and broken at room temperature. In this case the tensile strength was still 1,960 p.s.i.

		Tensile Strength (p.s.i.)	Elongation at Break (%)
Initial value		2,020	335
Broken at 200°C after ageing at 200°C	0 hrs.	340	140
	½ hr.	346	140
	1 hr.	350	135
	2 hrs.	385	150
	4 hrs.	300	130
Broken at room temperature after 4 hrs. at 200°C		1,960	315

It appears that with fairly short ageing periods the temperature of testing has more effect than the duration of the ageing period.

Compound 2

Incorporated a semi reinforcing furnace black.

The use of this black improved the processing qualities

The test specimens were aged for 5 minutes at temperatures ranging from 50°C to 175°C and were broken at the test temperatures.

Tensile strength fell rapidly from the initial value of 2,105 p.s.i. and at 175°C was as low as 255 p.s.i.

		Tensile Strength (p.s.i.)	Elongation at Break (%)
Initial value		2,105	220
Aged 5 minutes then broken at each temperature.	50°C	1,380	255
	75°C	885	205
	100°C	580	150
	125°C	395	130
	150°C	320	105
	175°C	255	85

1.1.3.2. Viton B.

This material, also made by Du Pont de Nemours, was reputed to have greater properties of heat resistance than Viton A.

Test specimens were aged for 5 minutes, ½, 1 and 4 hours at temperatures ranging from 50°C to 200°C and were broken at the ageing temperatures.

The results of the tensile tests are as shown below

Samples aged & tested at	Ageing times	Tensile strength (p.s.i.)
20°C	-	2,120
50°C	5 mins.	1,525
	½ hour	1,320
	1 hour	1,280
	4 hours	1,220
100°C	5 mins.	705
	½ hour	690
	1 hour	680
	4 hours	675
150°C	5 mins.	460
	½ hour	420
	1 hour	420
	4 hours	400
175°C	5 mins.	435
	½ hour	425
	1 hour	390
	4 hours	350
200°C	5 mins.	395
	½ hour	365
	1 hour	345
	4 hours	330

Discussion

Both Viton A and Viton B proved difficult to process and as neither possess outstanding properties of heat resistance no further work was done on them.

1.1.3.3. Kel-F Elastomer

Further attempts have been made to overcome the practical difficulties of curing Kel-F, using Lucidol S-50, 50:50 parts of benzoyl peroxide and silicone oil.

There was no appreciable softening effect and the compounds proved extremely difficult to process.

Kel-F remains of little interest as it is still very difficult to process.

1.1.4. Butyl Rubbers.

Tests were carried out on sulphur-cured butyl rubber to extend the work already done on resin-cured butyl and reported in S. & T.M. 18/59.

This work showed that butyl rubbers could be considered as suitable material for heat resistant tyres and consideration was given to constructing butyl rubber-steel wire tyres.

Further tests were made to measure the tear resistance of butyl and the butyl-steel wire adhesion, and how these are affected by heat.

1.1.4.1. Sulphur-Cured Butyl.

Tensile tests were carried out on a sulphur-cured butyl tread compound. The test pieces were aged for 5 minutes, ½, 1 and 4 hours at temperatures ranging from 50°C to 200°C and were broken at the ageing temperature.

Tensil strength fell steadily from an initial value of 2,195 p.s.i. at room temperature to a value of 200 p.s.i. - 300 p.s.i. at 200°C. The results are shown in Fig.2.

At 200°C the test pieces were sticky and completely useless. They were only slightly less so at 150°C.

Discussion

These tests considered in conjunction with those reported in S. & T.M.18/59, section 1.2.4., establish the superiority of resin-cured butyl at temperatures of the order 150°C-200°C.

Resin-cured butyl had been shown to possess good ageing characteristics, markedly better than those of natural rubber, up to 200°C and was considered to be a suitable material for heat resistant tyres. Consideration was given to the construction of resin-cured-steel wire tyres for heating and high speed tests.

However, sulphur-cured butyl was used in the construction of the initial butyl-steel tyres as it was better understood and was easier to process.

1.1.4.2. Tear Resistance

Further tests have been done to study the tear resistance at elevated temperatures of resin-cured butyl and sulphur-cured butyl and of natural rubber tread and casing compounds.

The tear resistance was measured using standard test pieces at temperatures ranging from room temperature to 200°C.

The results, presented in Fig.3, show little difference between the two butyl compounds, both of which are considerably worse than the natural rubber tread compound in this respect. The natural rubber casing compound gave figures of the same order as the butyl compounds.

1.1.4.3. Adhesion of Sulphur-Cured Butyl to Resin-Cured Butyl.

Consideration had been given to using sulphur-cured butyl in some components of the tyre and resin-cured butyl in others to ease tyre manufacture.

This would be practicable only if there were sufficient affinity between the two rubbers, so tests were made to measure the bond strength between the two.

Half and half slabs of sulphur-cured butyl and resin-cured butyl were cured and tear down adhesion tests on 1" strips were carried out after ageing. The results are given below. At 200°C when the adhesion was zero the sulphur-cured butyl had completely degraded and cracked on bending.

	Ageing Temperature		
	100°C	150°C	200°C
Ageing Time.	Adhesion of 1" strips - lb.		
½ hour	13.8	7.2	0
2 hours	12.0	6.6	0
4 hours	12.2	6.7	0

Discussion

In view of the low degree of bond strength between the two types of butyl, the idea of using both types in the tyre construction was dropped.

1.1.4.4. Adhesion of Butyl to Steel Wire.

1. Pull out adhesion tests were carried out, using ¾" x ¾" x ½" blocks, to assess the adhesion of resin-cured butyl and sulphur-cured butyl to untreated steel wire and to wire that had been treated by the Thixon two coat process. The wire used was 0.038" dia. bead wire.

The results are given below.

		Pull out Adhesion - lb.
Resin-cured butyl.	Untreated wire	6
	Thixon treated wire	49
Sulphur-cured butyl.	Untreated wire	34
	Thixon treated wire	28

As a result of these figures tests were carried out to determine the effect of ageing on adhesion between resin-cured butyl and treated wire, and between sulphur-cured butyl and untreated wire.

The results of pull out tests on the same size block are tabulated below:

Ageing Time		Ageing Temperature 100°C	150°C	200°C
		Pull Out Adhesion - lb.		
½ hour	Sulphur-cured untreated	17.0	13.3	0
	Resin-cured treated	27.0	13.7	13.0
2 hours	Sulphur-cured untreated	21.7	6.7	0
	Resin-cured treated	17.0	12.5	10.0
4 hours	Sulphur-cured untreated	20.0	12.3	0
	Resin-cured treated	20.5	11.7	9.0

2. Pull out adhesion tests were made to assess the effect of heat ageing on the adhesion of resin-cured butyl to 39 strand steel wire treated by the Thixon two coat process.

The steel wire was typical of that used in the construction of the steel-butyl tyre.

The tests using ¾" x ¾" x ½" blocks, were made at the ageing temperature with the results tabulated below:

Ageing and testing temperature: 150°C

	Pull Out Adhesion - lb.
Tested at room temperature	76.3
Ageing Time	
5 mins.	30.2
½ hour	23.8
1 hour	23.2
4 hour	18.5

Discussion

On the evidence presented above it was decided that the preferred form of construction of the steel-butyl tyre was resin-cured butyl with wire treated by the Thixon two coat process. However, sulphur-cured butyl with untreated wire was used in the construction of the initial steel-butyl tyre mainly because this form of butyl was better understood and was easier to process.

1.1.5. Halogenated Butyl Rubbers

Work has been carried out to see what, if any, greater heat resistance is imparted to resin-cured butyl by the incorporation of chloro-butyl in the compound.

In the first experiments the incorporation of chloro-butyl caused excessive retardation of the rate of cure. This defect was overcome by the use of neoprene as an accelerator.

Four compounds, incorporating very different proportions of chloro-butyl, were subsequently aged at 200°C and were broken at that temperature, with the results tabled below. -

Compound	Period of ageing @ 200°C	Temperature of test	Tensile Strength (p.s.i.)
A	None	Room temperature	1,921
	None	200°C	1,175
	2 hours	200°C	920
	4 hours	200°C	692
B	None	Room temperature	1,676
	None	200°C	760
	2 hours	200°C	801
	4 hours	200°C	605
C	None	Room temperature	1,219
	None	200°C	485
	2 hours	200°C	690
	4 hours	200°C	521
D	None	Room temperature	1,081
	None	200°C	252
	2 hours	200°C	617
	4 hours	200°C	452

Discussion

From these figures it was concluded that the incorporation of chloro-butyl does not impart better heat resistance to resin-cured butyl and no further work was done on this material.

1.1.6. S.B.R. Rubber

As earlier studies of an S.B.R. rubber had suggested that it had useful high temperature characteristics further work was done to study its heat ageing properties.

Three compounds were tested. Specimens were aged and tested at 100°C and 150°C. At 150°C fumes poured out of the ageing oven and this caused the experiments to be stopped at this stage.

The best ageing compound had a tensile strength of only 22% of its original after a 6 hour ageing period at 150°C.

Discussion

In view of these disappointing results it was considered that further studies of the high temperature properties could not be justified.

It is quite clear that these compounds could not be considered for use where prolonged heat soaking at temperatures of 150°C and above are to be experienced. This in spite of the evidence from high speed testing that this material will withstand transient high temperatures of the order of 200°C, e.g. at the end of a landing or taxi run, without undue degradation.

1.1.7. Low Temperature Polymer

The resistance to heat ageing of a typical low temperature polymer tread compound was compared with that of a typical natural rubber tread compound over the temperature range 140°C - 200°C. The test specimens were broken at the ageing temperature. The results are present in Fig.4.

Discussion.

Although the rate of fall off of tensile strength of the low temperature polymer compound is less than that of the natural rubber, the actual tensile strengths are much higher for the natural rubber compound.

In view of this evidence no further work was done on low temperature polymer compounds.

1.2. Natural Rubber

Further work was carried out on natural rubber tread and casing compounds to check work previously reported and to fill gaps in it.

1.2.1. Heat Ageing Tests

1. Tests were done to confirm the shape of the curve of Tensile Strength v. Temperature included as Fig.5 in S. & T.M.18/59.

   Standard test pieces of tread and casing compounds were aged at a range of temperature from 50°C to 200°C and were broken at the ageing temperatures.

   The results, presented as Figs.5A and 5B, confirm the general shape of the previously published curve.

   At temperature of 150°C and above surface stickiness or brittleness rule out the use of these compounds, apart from other considerations of their physical properties.

2. In order to determine whether the erratic results obtained previously were normal or due to some fault in test procedure, standard test samples of tread and casing compounds were aged at 10°C intervals from 125°C to 165°C and tensile tests were carried out at the ageing temperatures.

The results obtained, presented as Figs.5C and 5D., are of the same order as those obtained earlier and are similarly erratic.

Discussion

This work revealed nothing new but was valuable in providing confirmation of the results of previous work.

1.2.2. Prolonged Ageing

To determine to what extent long term ageing is more ruinous than short term ageing, standard test pieces of a casing compound were tested at temperatures up to 160°C after ageing for 10 days and 50 days at both 140°C and 160°C and without previous ageing.

The results are presented as Fig.5E. After ageing for 10 days at 160°C the test pieces became too brittle to test at temperatures above 100°C and after 50 days at 160°C the pieces were too hard and brittle for any tests to be performed on them.

Discussion

It is clear from these results that natural rubber compounds suffer continuous degradation on heat ageing their tensile strengths being progressively reduced.

The effect of prolonged ageing time from 4 hours to 10 days is quite marked, the compounds becoming virtually unusable at any temperature.

1.2.3. Tear Resistance

To provide a more complete statement of the fall-off in physical properties with temperature the tear resistance of a tread compound and a casing compound was measured at a range of temperatures from room temperature to 175°C.

See Section 1.1.4.2. and Fig.3.

Throughout the range of temperatures covered the tread compound has a tear resistance much higher than that of the casing compound which behaves much as butyl compounds.

The behaviour of both tread and casing compounds is similar in that the tear resistance is reduced progressively with temperature and at 175°C is 23% and 30%, respectively, of the room temperature value.

1.2.4. Pressurised Heating Tests.

Test rings of a natural rubber inner tube compound were heated in a pressure vessel containing air under pressure in an attempt to reproduce the deterioration observed in the inner surfaces of tubes which had been used with heat soaked tyres and in the inner liners of tubeless tyres. Reference S. & T.M.18/59, section 2.2.5.4.

Test Method.

Four test rings were prepared, 1.95" mean diameter and 0.16" square section. Two of the rings were supported such that they were stretched linearly 25%, the other two were left unstretched.

Two rings, one stretched, one unstretched, were placed in a sealed vessel containing air under pressure. The pressure vessel and the remaining two rings were placed in an oven maintained at a steady temperature of 130°C - 135°C.

After a period of heating the rings were examined visually and where possible they were subjected to elongation tests on a special ring testing machine. In some cases the rings were broken during removal from the pressure vessel and had to be tested in straight tension. The figures of load per side of ring to produce 100% stretch were recorded and those for a typical test are given below alongside comments on the appearance of the rings after the heating.

Typical results after 11 hours heating at 130-135°C.

	Appearance	Load for 100% stretch
In pressure vessel at 165 p.s.i.		
Unstretched	Very soft, no cracks, square section.	7/16 lb.
Stretched 25%	Very soft, no cracks, heat set, square section.	$\frac{3}{8}$ lb.
Outside pressure vessel.		
Unstretched	Surface untouched	2 lb.
Stretched 25%	Surface untouched, heat set.	$1\frac{3}{8}$ lb.

From the results obtained from these tests it is obvious that pressurised air accelerates decomposure and that the load required per side of ring to produce 100% elongation of the initially stretched test pieces is less than that required for the unstretched pieces. This is due to the heat setting of the initially stretched rings reducing their cross sectional area.

1.3. Nylon Cords

A series of tests were carried out to evaluate the heat resisting properties of type 600 nylon cord incorporating an antioxidant and to compare them with those of standard type 600 nylon cord.

Tests to measure breaking load and extensibility were carried out on a Scott inclined-plane textile testing machine equipped with a hot box totally enclosing the test cords. The hot box is heated by heating mats, a gentle stream of dry air being blown through the box to maintain an even temperature.

1.3.1. Effect of Temperature on Strength

The tensile properties of the two cords were first determined at room temperature conditions and then at a range of temperature up to 200°C.

The cord was mounted in the machine, the hot box closed and the heater switched on. Test temperature was achieved quite quickly, 200°C was reached in 7-8 minutes, and the cord was then broken.

It was found that the tensile strength of both cords drops approximately linearly with increasing temperature, the behaviour of both cords being similar and exhibiting a strength reduction of some 55% at 200°C.

	Breaking Load - lb.	
	At room temperature	At 200°C
Type 600 Nylon	30	13
Type 600 Nylon with antioxidant	30.6	13.8

Provided that the heating time is kept short, as it was in these tests, all the strength lost at the higher temperature is recovered when a return is made to room temperature conditions. Clearly there is an upper limit to the temperature at which the strength loss is reversible, beyond which permanent degradation sets in.

1.3.2. Heating in Nitrogen

Cords of type 600 nylon incorporating antioxidant were tested on the specially modified Scott machine. The tensile properties were first determined at room temperature then at 200°C, first with dry air blowing through the hot box and secondly using a stream of nitrogen in place of the dry air. The results are tabulated below:

	At room temperature	At 200°C.	
		In Air.	In Nitrogen.
Breaking load - lb.	27.8	11.3	12.9
Extension at break - %	20.3	18.0	22.6

The indication is that a small improvement in the resistance to ageing of this material is achieved by the exclusion of air.

1.3.3. Heat Aged Nylon Cords.

Further tests have been done on standard type 600 nylon, type 600 nylon with antioxidant and American type 700 nylon to determine their resistance to heat ageing.

The cords were oven aged for periods up to 7 hours at temperatures up to 220°C. and were subsequently tensile tested at room temperature on the Scott machine.

The results for cords aged at 160°C and 220°C are presented as Fig.6A and 6B.

These results demonstrate that when nylon cords are maintained at high temperatures for long periods some of the drop in strength at the high temperatures is irreversible and is not recovered when a return is made to room temperature conditions.

When aged at 160°C the type 600 nylon with antioxidant and the American type 700 nylon produced by DuPont de Nemours are comparable in that they do not suffer an appreciable strength loss after 7 hours ageing: under corresponding conditions the type 600 nylon lost about 55% of its strength.

When aged at 220°C. the type 600 nylon with antioxidant is better than the American type 700 nylon and both are much superior to normal type 600 nylon: type 600 nylon lost 50% of its strength after ½ hour ageing, type 700 nylon lost the same proportion in 1¾ hours and the type 600 nylon with antioxidant in about 3½ hours.

1.3.4. Fatigue Resistance

Laboratory belt fatigue tests indicated that the fatigue resistance of type 600 nylon with antioxidant should be as good as that of type 600 nylon. This was not borne out by machine tests on aircraft tyres.

Experimental tyres were constructed in the antioxidant cord in five sizes, Viscount nose, Comet main, Argonaut main, Dove main and Sabre main. Those in the first four sizes were subjected to structural fatigue machine tests, the Sabre tyres were high speed tested.

On the evidence from these tests it was considered to be definitely established that the fatigue performance was worse with the antioxidant cord than with normal type 600 nylon cord.

Subsequently supplies of type 600 nylon with antioxidant cord, to a slightly modified process, maintained the heat resistant properties and demonstrated a very much improved fatigue resistance, equal to that of type 600 nylon cord if not better, when tested in aircraft tyres.

1.3.5. Discussion

The type 600 nylon with antioxidant represents a considerable advance on type 600 nylon in that it possesses much improved resistance to temperature and heat ageing when heated in air, a particularly desirable property when high temperature processing of nylon cord is involved.

(continued)

When the cord is contained in rubber, as in a tyre, the differences in the temperature resistant properties of the two nylons must be somewhat less marked.

1.3.6. H.T.1. Nylon.

A new highly heat resistant nylon, H.T.1., has been developed in America by DuPont de Nemours. A small amount of this material was obtained for laboratory evaluation.

While the tenacity of this material in tyre cord form is not up to that of the normal nylon its high temperature properties are outstanding.

H.T.1. nylon chars at approximately 350°C. whereas normal nylons melt at 250°C.

In short term heating 60% of the room temperature strength is retained at a temperature of 200°C. and 20%-25% of the original strength is retained at a temperature of 300°C.

Further samples were oven aged and subsequently tensile tested at room temperature. When aged at 160°C. for periods up to 7 hours this material suffered no irreversible loss of strength. When aged at 220°C. for 6 hours there was a permanent drop in strength of only 15%-17%.

DuPont claim that adhesion to rubber is good. Limited tests on small samples did not substantiate this. Further experience with more samples might lead to a better technique and improved adhesion.

A further claim is that this material possesses extremely good flex resistance. No laboratory tests were made to explore this in view of the low adhesion obtained.

As this nylon is primarily designed for use where very high temperatures are experienced, a full evaluation would demand investigation of its adhesion to butyl, neoprene and other temperature resistant polymers, an investigation that was not practicable with the limited sample available.

This material is extremely expensive.

PART 2

2.1. Tests using Infra-Red Heating Chamber

2.1.1. Description of the Heating Chamber

The heating chamber is as described in S. & T.M.18/59, Section 2.1.1. and 2.1.2., with the exception that two Swartwout electro-pneumatic transducers have been fitted in place of those supplied originally.

2.1.2. Performance of the Heating Chamber

The performance of the heating chamber has been unsatisfactory in that the automatic control feature has not afforded adequate control of hot plate temperature. All tests have had to be carried out using manual control with consequent variation in plate temperature.

Redesigned transducers were fitted by the equipment manufacturer in an attempt to improve the automatic control feature. This was successful to a point, but better control is still achieved manually.

2.2. Heating Tyres prior to High Speed Testing

2.2.1. Standard Construction Tyres with Reduced Tread

The object of these tests was to extend the work to establish the curve relating the performance of standard tyres to heat soak temperature, reported in S. & T.M.18/59, section 2.2.3., and to see the effect on performance of using tyres with very thin treads.

2.2.1.1. Test Method

The test procedure followed was that described fully in S. & T.M.18/59, section 2.2.3.1.

2.2.1.2. Thin Treaded Tyre

This tyre had a moderately thin tread similar to the other tyres tested to produce the upper curve of the graph Fig.12 of S. & T.M.18/59.

The temperature of the tyre, measured at the breakers, was 110°C. at the start of each landing run. The tyre completed 4½ landings, i.e. it failed towards the end of the fifth landing run, which is a higher performance than expected from the above curve.

2.2.1.3. Very Thin Treaded Tyres

Two tyres were tested. They were similar to those previously tested except that they had very thin treads.

1. This tyre was heat soaked to a temperature of 110°C–120°C at the breakers and was then transferred to the high speed test machine.

(continued)

It was observed that the breaker temperature drop from the time the tyre was removed from the heating chamber to the start of the high speed landing run was greater with this tyre than had been expected. This is attributed to the reduced bulk of the thinner tread. The breaker temperature at the start of each landing run was 90°C.

The tyre completed $9\frac{1}{4}$ landings before exhibiting the first signs of failure.

This high speed performance is much superior to that of a tyre having a moderately thin tread. In order to achieve 9 landings of similar severity a moderately thin treaded tyre would have to start each landing run at a temperature no higher than 40°C-50°C.

2. A second very thin treaded tyre was heat soaked and subsequently high speed tested. Again, the results show how much the high speed performance is improved by using such a thin tread, but it was not possible to find the ultimate failure point of the tyre as the driving engine of the high speed machine caught fire and the test had to be stopped.

The average breaker temperature at the start of each landing run was 115°C.

The tyre completed 8 landings without signs of failure.

2.2.1.4. Discussion

Although it can be argued that a thinner treaded tyre will reach a higher temperature in a given time when soaked in a high temperature environment, it must be remembered that under these conditions of thin tread and high temperature the rate of cooling prior to landing is high and the temperature rise during the landing run is low.

The results of these later tests have been added to Fig.12 of S. & T.M.18/59 which is reproduced here as Fig.7. It is clear from this presentation that a striking improvement in the performance of standard construction tyres is achieved by considerably reducing the tread thickness. Whereas it would be foolish to suggest a performance curve for these very thin treaded tyres, the indication is that such a tyre heat soaked to a temperature of 135°C. would be capable of 2-3 landings.

2.2.2. Simulated "Two Sortie" Heating and High Speed Test

A series of tests were carried out to establish the probable behaviour of a standard tyre under the simulated conditions of two sorties of a typical high speed strike aircraft with a short turn-round time of 15 minutes between sorties. The ambient air temperature in the heating chamber, simulating the tyre retraction bay, was maintained at approximately 130°C.

Under these conditions the standard tyres behaved satisfactorily, exhibiting no signs of failure at the end of the tests.

A typical test is described below.

The tyre was placed in the heating chamber and pre-heated. This involved a 10-13 minute temperature rise and 52 minutes soak at approximately constant surrounding air temperature. Air temperature adjacent to the tyre shoulders was maintained at 130°C-135°C.

At the end of the pre-heating the tyre temperatures were 100°C at the crown and 110°C at the shoulder.

The tyre was then transferred to the high speed testing machine and a high speed landing run carried out with the minimum of delay.

The tyre was allowed to cool naturally, no forced convection, for 15 minutes and then subjected to a high speed take-off run before being replaced in the heating chamber as quickly as possible.

In the heating chamber the tyre was immediately subjected to a second heat soak, involving a 15 minute rise of air temperature and a 40 minute dwell period at surrounding air temperature of 130°C-135°C. This was followed by a rapid transfer to the high speed machine and a high speed landing - 15 minute cooling - high speed take-off cycle exactly as before.

The tyre was rapidly returned to the heating chamber where it was given a third heat soak, 10 minute temperature rise and 25 minute dwell in ambient air temperature of 130°C-135°C., before being transferred to the high speed machine for a third high speed landing - 15 minutes cooling - high speed take-off cycle.

The tyre temperatures before and after the high speed runs were:-

Run		Temperature - °C. Crown	Shoulder
First Landing	Start	77	82
	Finish	107	101
First take off	Start	80	85
	Finish	127	121
Second Landing	Start	95	105
	Finish	134	134

(Continued)

Run		Temperature - °C Crown	Shoulder
Second take off	Start	100	98
	Finish	143	135
Third Landing	Start	95	98
	Finish	125	118
Third take off	Start	90	92
	Finish	142	122

The tyre, which satisfactorily completed this test without sign of failure, was subjected to the third heat soak and high speed test cycle in order to demonstrate that it had an adequate margin of performance after completing the simulated two-sortie test.

2.3. Casing Burst Tests at High Temperatures

2.3.1. Tyre Constructed with Heat-Resistant Nylon

An experimental Comet main wheel tyre (36x10.00-18) constructed with type 600 nylon with antioxidant cord was heated and burst while hot. The heating and bursting technique used was that described for the series of burst tests on heated tyres reported in S. & T.M. 18/59, section 2.2.5., except that the tyre was inflated to service pressure at the beginning of the heating test and the inflation pressure was allowed to rise naturally with temperature.

The tyre burst violently at the bead and the carcase rose to a considerable height.

The result from this test when plotted on Fig.14, (S. & T.M. 18/59) falls within the scatter of results from previous tests on the same sized tyres, constructed with normal type 600 nylon, heated to 150°C-200°C. The burst pressure was marginally greater than that for tyre 10282, October 1957, which was heated to the same degree.

It can be argued that this result points to an improved heat resistance for the antioxidant cord as:

(a) the tyre had been at a considerably higher pressure during heating which had resulted in a greater increase in tyre dimensions during the heating cycle.

(b) the casing of this tyre was not the point of initial failure, the bead wires had broken first. The sidewall had failed first on tyre 10282, October 1957.

Run		Temperature - °C Crown	Shoulder
Second take off	Start	100	98
	Finish	143	135
Third Landing	Start	95	98
	Finish	125	118
Third take off	Start	90	92
	Finish	142	122

The tyre, which satisfactorily completed this test without sign of failure, was subjected to the third heat soak and high speed test cycle in order to demonstrate that it had an adequate margin of performance after completing the simulated two-sortie test.

2.3. Casing Burst Tests at High Temperatures

2.3.1. Tyre Constructed with Heat-Resistant Nylon

An experimental Comet main wheel tyre (36x10.00-18) constructed with type 600 nylon with antioxidant cord was heated and burst while hot. The heating and bursting technique used was that described for the series of burst tests on heated tyres reported in S. & T.M. 18/59, section 2.2.5., except that the tyre was inflated to service pressure at the beginning of the heating test and the inflation pressure was allowed to rise naturally with temperature.

The tyre burst violently at the bead and the carcase rose to a considerable height.

The result from this test when plotted on Fig.14, (S. & T.M. 18/59) falls within the scatter of results from previous tests on the same sized tyres, constructed with normal type 600 nylon, heated to 150°C-200°C. The burst pressure was marginally greater than that for tyre 10282, October 1957, which was heated to the same degree.

It can be argued that this result points to an improved heat resistance for the antioxidant cord as:

(a) the tyre had been at a considerably higher pressure during heating which had resulted in a greater increase in tyre dimensions during the heating cycle.

(b) the casing of this tyre was not the point of initial failure, the bead wires had broken first. The sidewall had failed first on tyre 10282, October 1957.

2.3.2. Steel Cord - Natural Rubber Tyre

Heating tests were carried out on a steel cord-natural rubber aircraft tyre, 33x6.75-20 of dual bead crown overlap construction, with the object of evaluating the strength of this construction at high temperature and investigating the pressure build-up. The tyre was fully inflated before heating and the pressure was allowed to build-up during the heating.

During the second protracted heating the tyre burst, considerably damaging the heating chamber.

The tyre, which had 6 plies of steel cord in the crown, was designed to operate at an inflation pressure of 350 p.s.o. with an estimated casing burst pressure of 1,300 p.s.i. - 1,500 p.s.i. at room temperature.

As a safety precaution, prior to the heating tests, the tyre was fitted to a heavy test wheel and hydraulically checked to 800p.s.i. The tyre appeared perfectly sound at this pressure.

For the first heating test the tyre was inflated, initially, to 345 p.s.i. After 5 hours heating the tyre temperature had risen to 150°C-160°C. and the inflation pressure had reached 510 p.s.i. At this point a valve connection burst and the tyre deflated.

The inflation pressure was set to 300 p.s.i. at the start of the second heating test in which the hot plates were maintained at 210°C-230°C., about 25°C higher than in the first test. After 5 hours the tyre temperature had risen to 160°C-170°C. and the inflation pressure to about 510 p.s.i. In this condition the crown of the tyre burst and the heating chamber suffered extensive damage.

Investigation revealed that the failure was due to uneven stress distribution in the layers of casing plies caused by heat degradation of the natural rubber inner liner; it had been forced through the steel cords of the first ply and this ply was no longer taking part of the casing stress during part of the inflation pressure build-up period; the outer plies were not strong enough, by themselves, to contain the increased inflation pressure.

2.4. Assessment of Heat Insulators.

In connection with the problem of in-flight heating of tyres during retraction, work has been done using the high temperature oven to evaluate methods of reducing the temperature build-up in the tyre as a result of skin heating.

Tests were made on tyres, size 36x10.00-18, using -

(a) air only.

(b) Refrasil blanket (¼" thick),

(c) Rubberised asbestos sheet (0.3" thick),

(d) Urethane foam sheet (0.25" thick),

(continued)

between the upper plate of the oven and the tyre. Items (a), (b) and (c) were fixed in turn to the under side of the upper plate which was only plate heated during the tests.

With the tyre in the oven with a pre-set separation between the top plate and tyre sidewall the top plate was maintained at a set temperature for a period of 4-5 hours until the tyre sidewall and shoulder had reached a steady temperature. The temperatures of hot plate and tyre were recorded.

Top Plate - Tyre Separation		Temperature Difference Top Plate-Sidewall	Temperature Difference Top Plate-Shoulder
Top Plate at 200°C.			
1¾"	Air	70°C	105°C
1¾"	(1½" Air (¼" Refrasil blanket	135°C	160°C
1"	(¾" Air (¼" Urethane Foam	85°C-90°C	125°C
Top Plate at 155°C-160°C.			
1¾"	Air	105°C	115°C
1"	(¾" Air (¼" Refrasil blanket	100°C-105°C	-
1"	(¾" Air (¼" Asbestos sheet	65°C-70°C	95°C

It is concluded from these results that considerable reduction in heat transfer is achieved by the use of a layer of heat insulation material immediately adjacent to the hot plate.

When the hot plate was maintained at 160°C. the tyre sidewall temperature was the same when the plate-tyre separation was 1¾" air and when the separation was ¾" air plus ¼" thick Refrasil blanket, i.e. under these conditions a ¼" thick Refrasil blanket has the same insulating effect as 1" layer of air.

When the hot plate was maintained at 200°C with a plate-tyre separation of 1¾" the effect of including a ¼" thick refrasil blanket immediately below the hot plate was a reduction in tyre temperature of 55°C-65°C.

The ¼" thick rubberised asbestos sheet is less effective than the ¼" thick Refrasil blanket. Under the conditions of 160°C hot plate and total separation of 1" the substitution of the Refrasil blanket for asbestos sheet resulted in a reduction of sidewall temperature of the order of 35°C.

(continued)

The urethane foam sheet, formed by spraying on to the hot plate, cannot be considered for use where it would be subjected to temperatures of 160°C and above for long periods. After a test of 4½ hours with the hot plate at 160°C the foam presented a scorched appearance and showed signs of brittleness. After a further test, this time with the hot plate at 200°C, the material was very brittle and crumbled under slight pressure.

PART III.

3.1. Tyre Cooling Tests in Wind Tunnels

The purpose of these tests was to find the rate of cooling of heated aircraft tyres and wheels when subjected to a cooling wind at various speeds, as when extended into the slipstream before the landing run.

Two test programmes were carried out: the first in the wind tunnel at Bristol Siddeley Establishment, Ansty, at wind speeds of 35 f.p.s.-160 f.p.s.; the second in a wind tunnel at Vickers-Armstrong (Aircraft) Ltd., Weybridge, at wind speeds of 50 f.p.s.-260 f.p.s.

A Comet mainwheel tyre assembly was used in both test programmes as it is of average size and conventional design. It is believed that results that might have been obtained from other similar assemblies would not have differed significantly from those observed during these tests.

3.2. First Test Programme

This work was carried out at Bristol Siddeley Establishment at Ansty.

3.2.1. Method

A 36 x 10.00-18 triple bead tyre was built with thermocouples incorporated in the construction. The tyre was supported in an electrically heated oven adjacent to the wind tunnel where, after about three hours heating, the tyre reached steady temperatures between 150°C and 200°C.

The tyre was then transferred as quickly as possible to the wind tunnel where it was located end on to the wind direction and the wind was started. The temperature of various parts of the tyre were recorded during the heating and cooling processes. The programme consisted of five such tests, each one with a different wind speed.

3.2.2. The Tyre and Wheel

18 thermocouples were built into the tyre. These were positioned in three clusters. Two clusters were diametrically opposed on the same side of the tyre, the third cluster being on the opposite side of the tyre, orientated at 90° from the others. Each cluster consisted of three thermocouples in the beads, one in the apex strip above each coil, and three in the crown region of the tyre, one at the inside case, one at mid case and one at the base of the tread. These thermocouples were connected to a 16 point recorder, only four thermocouples of the third cluster being connected.

The leads of the thermocouples at the inner liner were taken through the sidewall casing and this caused a potential leak path.

(continued)

At first the tyre held pressure satisfactorily but after the first heating a slow leak developed and after the second heating the tests were carried out with the tyre uninflated.

The wheel used was a tubeless wheel bushed and fitted with a hollow axle, drilled to enable the thermocouple leads to be passed through and brought out at one end. The axle had a key way milled into it to enable the wheel and tyre to be rotated when the tyre was in the oven.

3.2.3. The Oven.

The oven consisted of a double skin metal box open at the bottom so that when the tyre-wheel assembly was mounted upright, on a small trolley, the oven could be lowered over the tyre. There were 8 electric heaters in the oven, arranged 4 each side. Unfortunately the tyre sidewall-oven wall clearance was small and the heaters tended to scorch the tyre sidewalls.

There was no means of circulating the air in the oven and the tyre had to be rotated by hand to obtain even soak temperatures and to reduce the severity of the local sidewall scorching.

3.2.4. Wind Tunnel.

This was of the straight through type with an observation chamber of 15 sq.ft. cross sectional area, square shaped, with rounded corners, of 4ft. side.

With the obstruction of the test assembly the maximum attainable steady air speed was 160 f.p.s. and the slowest obtainable steady air speed was 35 f.p.s.

The required steady air speed could be attained within 60 seconds of switching on.

3.2.5. Results

Five cooling tests were carried out, at wind speeds of 35, 61, 100, 130 and 160 f.p.s. The heating of the assembly and its transfer into the wind tunnel were similar on each occasion.

In an endeavour to obtain the relationship between the rate of cooling and position around the tyre, relative to the wind direction, each cooling test was carried out with the tyre at different positions, rotationally.

The cooling curves for the various parts of the tyre with a wind speed of 160 f.p.s. are shown in Fig.8. This family of curves is typical of those obtained for each test except that the cooling rate was slightly reduced at the slower air speeds.

Table I records the extent of the temperature fall in the various parts of the tyre after 20 minutes cooling at the different wind speeds.

Table II records the effect of position around the tyre and wind speed on the cooling rate, effects which are represented in graphical form in Fig.9.

(continued)

3.2.6. Discussion

1. The most rapid cooling occurred at the base of the tread, the tread-carcase interface; the cooling of the mid-carcase was slower.

   This is of considerable significance since pre-heated tyres are most susceptible to failure of the tread separation type when used under high speed conditions. Rapid cooling is therefore essential for this part of the tyre. High initial bead temperatures are not so critical except where long taxying distances may be involved after touchdown.

2. From Fig.8 and Table I. it can be seen that the toe coil was the slowest cooling part of the tyre. It was noted during the warm up periods that this was the slowest part of the tyre to attain a given temperature. The mid coil was nearly as slow as the toe coil to change its temperature but the heel coil changed its temperature much more rapidly due, presumably, to the proximity of the metal flange. In each of the cooling tests the curves for the mid and toe coils formed a cooling curve band having a cooling rate much lower than that for any other part of the tyre.

   From a consideration of curves 4, 9 and 14 the wheel flange appears to have accelerated the cooling of the heel in the early stages, but after some 30-40 minutes the influence of the flange is less marked. At the end of each test, after about 40 minutes cooling, the wheel was felt by hand. It was found to be really cold to the touch whereas the tyre still felt warm.

3. Fig.9 and Table II show that wind speed does have an effect on cooling rate and that the effect is more marked at the lower speeds. If the curve is continued towards zero airspeed it will rise steeply as the difference in cooling rate between natural convection cooling and forced convection is considerable.

   Subsidiary tests were carried out to find out how quickly the base of the tread cools from 135°C to 115°C in virtually still air. Where the whole tyre and wheel assembly had been heated initially, it took some 8 minutes, but where the tread alone was hot, as from a take-off, the base of the tread cooled in 5 minutes.

4. It is not possible to conclude from Table II whether there is a general trend for the front of the tyre to be cooled quicker than the rear.

3.3. Second Test Programme

This work was carried out at Vickers-Armstrong (Aircraft) Ltd., Weybridge.

3.3.1. Method

The method employed was substantially the same as that used in the first test programme.

3.3.2. The Tyre and Wheel

A Comet mainwheel assembly, complete with brake, was used.

Twelve thermocouples were inserted into the tyre and connected to two 6-channel recorders.

On the non brake side 6 thermocouples were placed in the bead coil apex: one in the heel coil apex; one in the mid coil apex; four spaced 90° apart, in the toe coil apex. A further thermocouple was placed in the brake side toe coil apex.

Four thermocouples were placed in the crown of the tyre at inner liner level. These were spaced at 90° intervals. A fifth was inserted in the crown at the base of the tread.

The tyre was inflated to a pressure of approximately 20 p.s.i. before the tests, the pressure being allowed to increase naturally during the heating cycles.

3.3.3. The Oven

The oven consisted of a double skin steel box with one end detachable to allow the test assembly, mounted on a long axle, to be removed. On replacing the door a sealed box was obtained affording a minimum of heat loss. Air was circulated by an externally mounted blower connected to the box via a small compartment containing heating elements.

3.3.4. Wind Tunnel

This was the 13ft. x 9ft. tunnel. With the obstruction of the test assembly the maximum attinable steady air speed was 260 f.p.s. Approximately 30 seconds was required to achieve this speed from the time of starting up the tunnel.

3.3.5. Results

Five cooling tests were carried out, at wind speeds of 50, 100, 160, 210 and 260 f.p.s. The heating of the assembly and its transfer into the tunnel were similar on each occasion.

The temperature recordings were examined and replotted in more conventional form.

Fig.10 shows the relative cooling rates from 120°C above ambient of various parts of the tyre at a wind speed of 160 f.p.s. This family of curves is typical of those obtained for each test except that the cooling rate was slightly reduced at the slower air speeds.

Fig.11 illustrates the cooling rates at the base of tread and inner liner over the range of wind speeds.

The effect of wind speed on the cooling rate of different positions within the tyre is represented in graphical form in Fig.12.

(continued)

3.3.6. Discussion

1. The most rapid cooling occured at the base of the tread. The cooling of the inner liner was much slower in the early stages.

2. The bead coils remote from the wheel flange took the longest time to cool, due to the poor conductivity of the rubber. The heel coil cooled much more rapidly due, presumably, to the proximity of the metal flange.

   There was no significant differences between the cooling rates recorded at the front and the rear positions in the tyre.

3. Fig.11. shows that at wind speeds up to 100 f.p.s. there was an improvement in the cooling rate at both the inner liner and the base of the tread, and that there was very little improvement at higher wind speeds.

   The most significant fact is that a gentle breeze gave a much higher cooling rate than still air.

4. Fig.12 illustrates that no part of the tyre was greatly assisted in cooling by increasing the wind speed above about 100 f.p.s.

3.4. Conclusions

1. There is a broad agreement in the results from both test programmes.

2. The most significant fact to emerge is that whereas the tyre cooling rate increases with wind speed, the tyre cools much more rapidly in a breeze than it does in still air, there is nothing to be gained by increasing the wind speed above about 100 f.p.s. (70 m.p.h.)

3. The most rapid cooling takes place at the base of the tread, the slowest cooling at the bead coils.

   This is an important feature as pre-heated tyres are most susceptible to tread separation failure, under high speed operation, and rapid cooling of this part of the tyre is very desirable. High initial bead temperatures are not so critical except where long taxying distances may be involved after touchdown.

4. The cooling rate of any region around the circumference of the tyres does not vary with its position relative to the wind direction.

PART IV.

4.1. Special Heat Resistant Tyres

4.1.1. Design Consideration

It was concluded in S. & T.M.18/59, part IV, that steel cord casings form the only practical basis for high temperature tyres and that in this context the crown overlap type of construction offered advantages over the conventional type of construction.

The results of the tests made on butyl rubbers showed this material to be the most suitable heat resistant polymer when processing and adhesion properties are taken into account.

A programme of work has been carried out to develop steel cord-natural rubber and steel cord-butyl rubber tyres in the crown overlap type of construction. In the later tyres the two outer steel ply overlaps were buried in the tread rubber, providing tread reinforcement. It was considered that with this construction the tyre would be capable of completing a landing run when the steel-polymer adhesion had broken down.

Much of the work was concentrated on developing steel cord processing techniques, particularly with the butyl rubbers. A workable technique was developed of rubbering each cord individually and then drum winding them to form a construction ply. A thin sheet of rubber or butyl was calendered each side of the ply to remove the corrugation of the surface. This eased tyre building and very much reduced the risk of trapping air between plies, an important consideration when butyl rubbers are used.

The natural rubber tyres were of dual bead construction. Tyre making considerations led to a change of design to single bead construction for the first butyl tyres. This necessitated a large bead coil.

Bursting of the first tyre in the bead region at low pressure and flange cutting of the outer ply of the second tyre during high speed tests were both attributable to the large single bead. Consequently, subsequent butyl tyres were to a revised, dual bead design.

4.2. Steel Cord - Natural Rubber Tyres.

4.2.1. High Speed and Fatigue Tests.

Two steel cord-natural rubber aircraft tyres, size 33x6.75-20, were machine tested at room temperature. Both were of dual bead, crown overlap construction with block pattern tread.

One was tested to failure on the high speed testing machine, giving a satisfactory performance. The failure occurred as reversion of the rubber in the blocks of the tread after 20 take-off and 24 landing runs at speeds of 180-240 m.p.h. The steel cord tyre ran approximately 10°C hotter than a typical nylon cord tyre under the same conditions but there was no looseness between the tread and casing.

(continued)

The high speed tests on the second tyre were curtailed by extensive refitting of the high speed machine and the tyre was subjected to a standard slow speed fatigue test. The performance on this test was satisfactory, demonstrating adequate structural fatigue life.

4.2.2. Heat Soak Tests.

One tyre was subjected to a prolonged heat soak test. This test is covered in detail in section 2.3.2.

4.3. Steel Cord-Butyl Rubber Tyres.

4.3.1. Sulphur-cured Butyl

First attempts to make a dual bead construction tyre failed. There was insufficient tack to hold the steel plies and bead coils together during the making operating. The design was changed to single bead and one tyre was produced to this construction.

During hydraulic over inflation pressure check, carried out as a safeguard against tyre bursts during heating cycles, this tyre burst at the bead at 800 p.s.i. It was considered that this failure was due to the fact that the tyre was of single bead construction, necessitating a large bead coil, and the burst was probably aggravated by the wheel flange height on the standard wheel being too low for this form of construction.

4.3.2. Resin-cured Butyl

During hydraulic pressure checking of the first steel cord-resin-cured butyl tyre some distortion of the tyre was noted; subsequent X.Ray examination showed slackness in the steel casing.

This tyre was subjected to a series of 7 high speed landing tests at speeds up to 150 m.p.h. At the end of the last landing test, started with a base of tread temperature of 80°C-90°C., a bulge had appeared at the clinch region. Examination revealed that the wheel flange had nibbled through the outermost ply at the clinch and this ply had separated from the rest of the casing, locally. The tyre was considered to be fit for heating tests in the heating rig.

This tyre was given a 5 hour heat soak in the later stages of which the crown and shoulder base of tread temperatures were 160°C-180°C. The inflation pressure, initially 100 p.s.i., was kept below 150 p.s.i. throughout. No scorching or cracking was visible on the sidewalls.

Study of this tyre construction enabled steps to be taken to reduce the likelihood of casing irregularity in subsequent tyres.

The second tyre behaved satisfactorily on initial hydraulic over inflation check, demonstrating no distortion. It was then subjected to two heat soak tests.

(continued)

The first heat soak was ended after 4 hours when a seal failed in the inflation circuit. The base of tread temperatures were -

Shoulder	...	$165^{\circ}C$ - $185^{\circ}C$
Crown	...	$160^{\circ}C$ - $175^{\circ}C$

During the second, prolonged heat soak of $6\frac{1}{2}$ hours the tyre achieved temperatures -

Shoulder	...	$195^{\circ}C$ - $215^{\circ}C$
Crown	...	$185^{\circ}C$ - $205^{\circ}C$

The tyre appeared undamaged apart from some very small blisters in the crown region. As a safety precaution the tyre was hydraulically over inflated before being given a further heat soak, prior to being high speed tested while hot.

The tyre was heat soaked for 4 hours and then transferred with the minimum of delay to the High Speed Test machine where it was inflated to 350 p.s.i. The crown temperature immediately before the first landing test was $175^{\circ}C$-$180^{\circ}C$.

After 4 seconds of the first landing test, 150 m.p.h.- 50 m.p.h. in 36 seconds, a piece of tread rubber was thrown and after 15 seconds the tyre deflated through tube failure. The tube was necessitated by the fitting of flange raisers to the test wheel in an attempt to eliminate the troubles experienced with the earlier figures.

Further development work led to the production of a tyre in a dual bead construction.

This third tyre behaved satisfactorily on hydraulic over inflation to 800 p.s.i., exhibiting no distortion. It was then given a $4\frac{1}{2}$ hour heat soak before being transferred immediately to the High Speed Test machine for high speed landing tests.

At the end of the heat soak large areas of looseness were evident, particularly in the shoulder and crown region. Even so, it was considered worth-while carrying out the high speed tests.

On attempted inflation to 350 p.s.i. the tube failed and air was seen to be escaping through the casing. It was clear that there was nothing to be gained by further heat soaking and subsequent high speed testing this tyre.

TABLE I

Ref: Section 3.2.5.

35			61			100			130			160	
150			158			N.R.			153			198	
		A			A			A			A		
	B			B			B			B			B
T	87		B					194		78	180	F	71
O	133	175	O	93*	181	R	124	187	R	130	187	R	112
P	107	165	T	101	171	E	101	179	E	107	188	O	97
	141	157	T	137	164	A	143	169	A	148	184	N	146
	149	154	O M	146	163	R	154	168	R	157	182	T	156
R	75	171	F	79	180	B	76	195	B	68	188	T	71
E	114	167	R O	122	177	O T	119	195	O T	82*	200	O	129
A	105	167		109	171	T	105	181	T	107	197	P	112
R	134	160	N T	141	165	O N	143	178	O M	149	196		161
B	81	60	T	78	180	F	81	179	F	81	170	R	70
O	112	154	O	107	188	R	109	184	R	113	192	E	106
T	87*	154	P	117	185	O	122	182	O	125	189	A	115
T	118	154		108	175	N	107	172	N	107	186	R	112
O	147	146		138	172	T	150	167	T	147	188		156
M	150	146		144	171		156	167		156	187		164
0			10			25			0			0	
0			N.R.			12			0			0	

* Suspect Observation

TABLE II

Ref: Section 3.2.5.

Time taken for temperature to fall from 135°C to 115°C.

Wind Speed - f.p.s.		35		61		100		130		160	
Position in Tyre.	Orientation	T-C No.	Mins.	T-C No.	Mins.	T-C No.	Mins.	T-C No.	Mins.	T-C No.	Mins.
Base of Tread	Rear	7	4.5			1	open	1	2.9	11	2.8
	Top	1	4.0	11	3.0					7	2.6
	Front			7	3.1	11	3.5	11	3.3	1	2.8
	Bottom	11	4.0	1	open	7	3.0	7	2.8		
Inner Liner	Rear	8	7.2			3	5.4	3	5.0	13	5.1
	Top	3	6.7	13	5.9					8	4.5
	Front			8	5.8	13	5.1	13	5.0	3	4.0
	Bottom	13	2.0*	3	2.3*	8	5.0	8	2.7*		
Mid Coil	Rear	10	10.5			5	9.1	5	8.5	15	7.7
	Top	5	10.2	15	10.2					10	7.5
	Front			10	8.7	15	8.6	15	8.1	5	7.0
	Bottom	15	9.4	5	8.6	10	9.1	10	6.7		
	Rear	9	7.0			4	5.2	4	5.9	14	5.8
	Top	4	6.7	14	6.8					9	5.7
	Front			9	6.0	14	5.8	14	5.8	4	4.8
	Bottom	14	7.7	4	5.6	9	5.9	9	5.4		

* Suspect reading

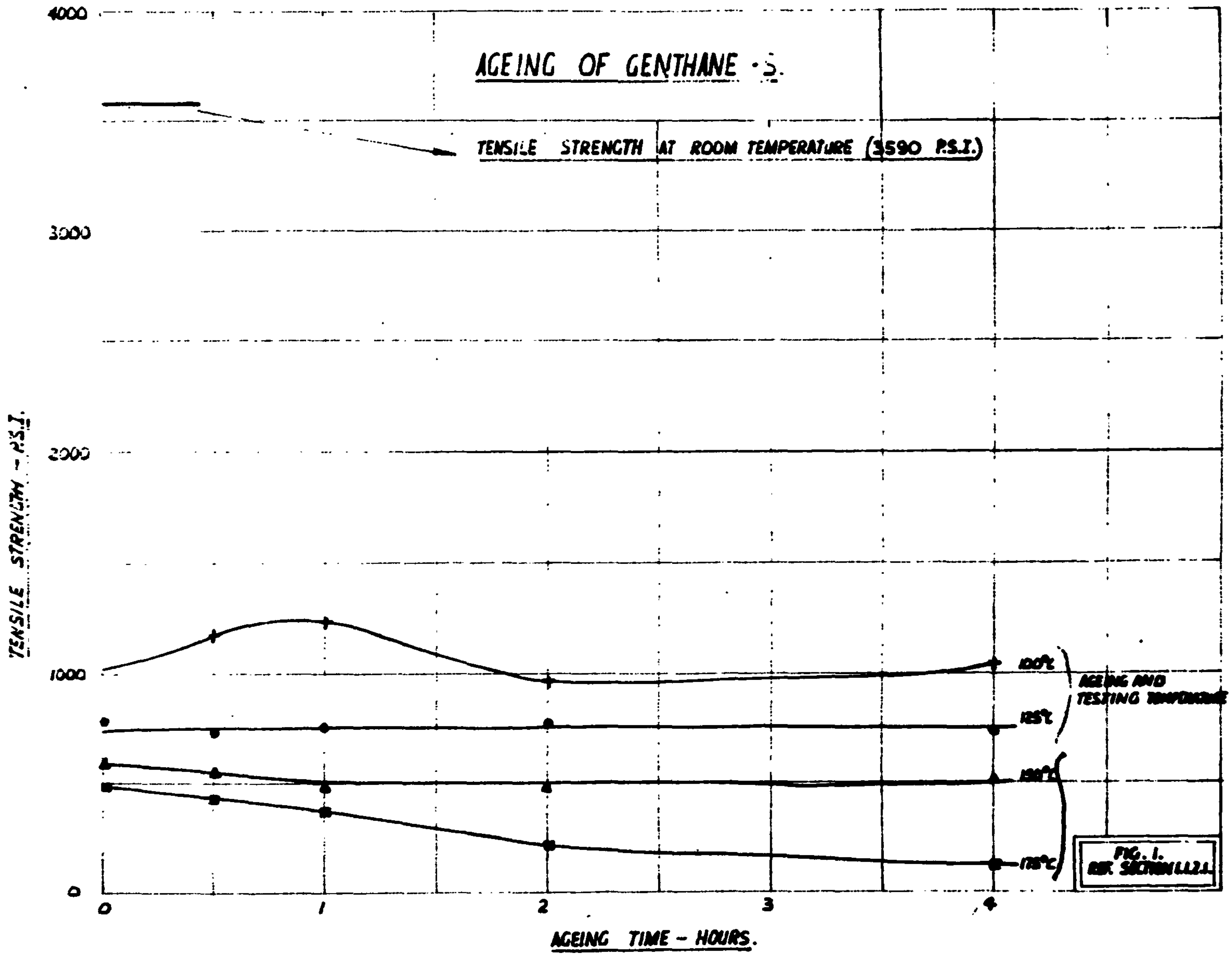


FIG. 1.
REF. SECTION 1.1.2.1.

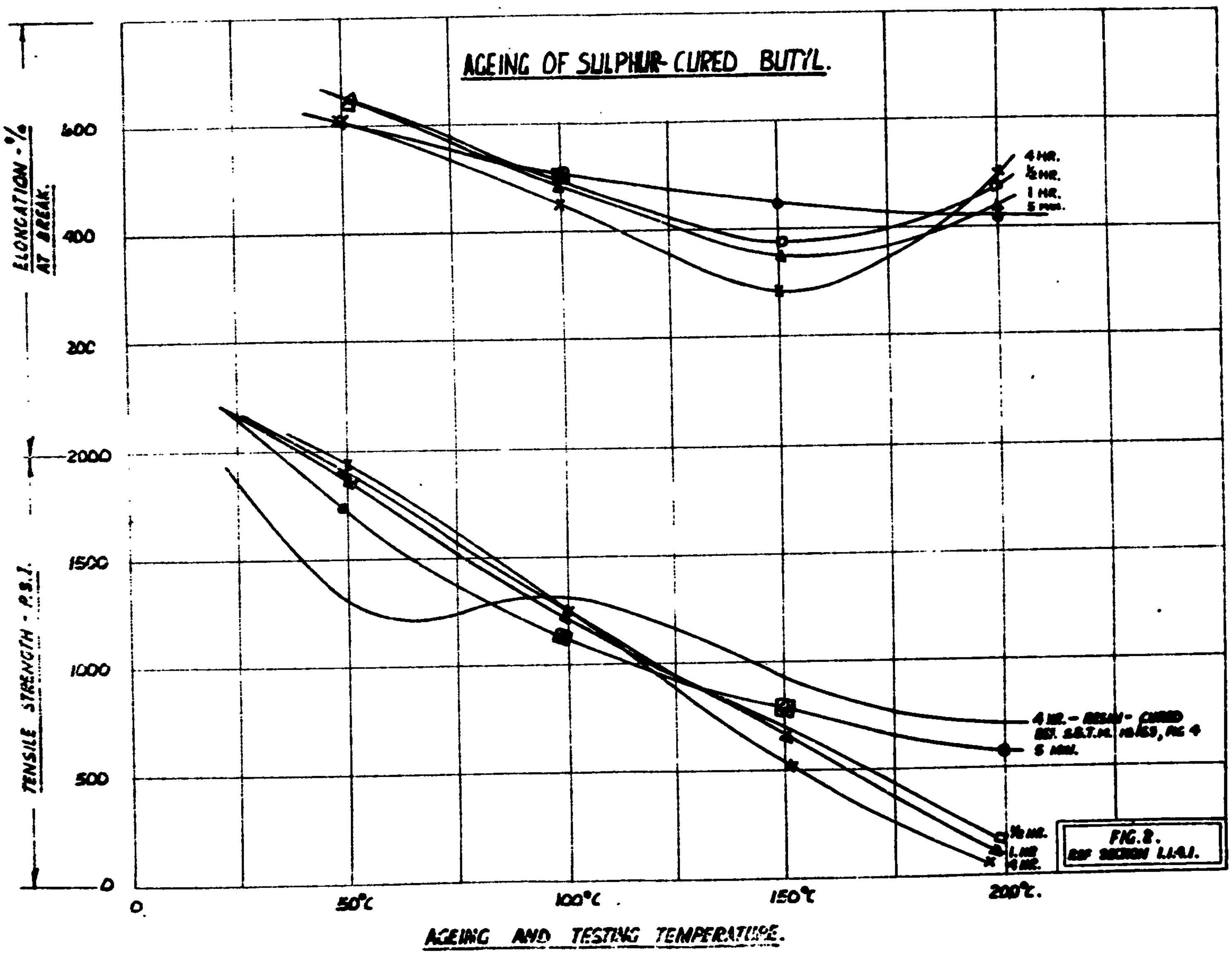


FIG. 2.
REF SECTION 1.1.4.1.

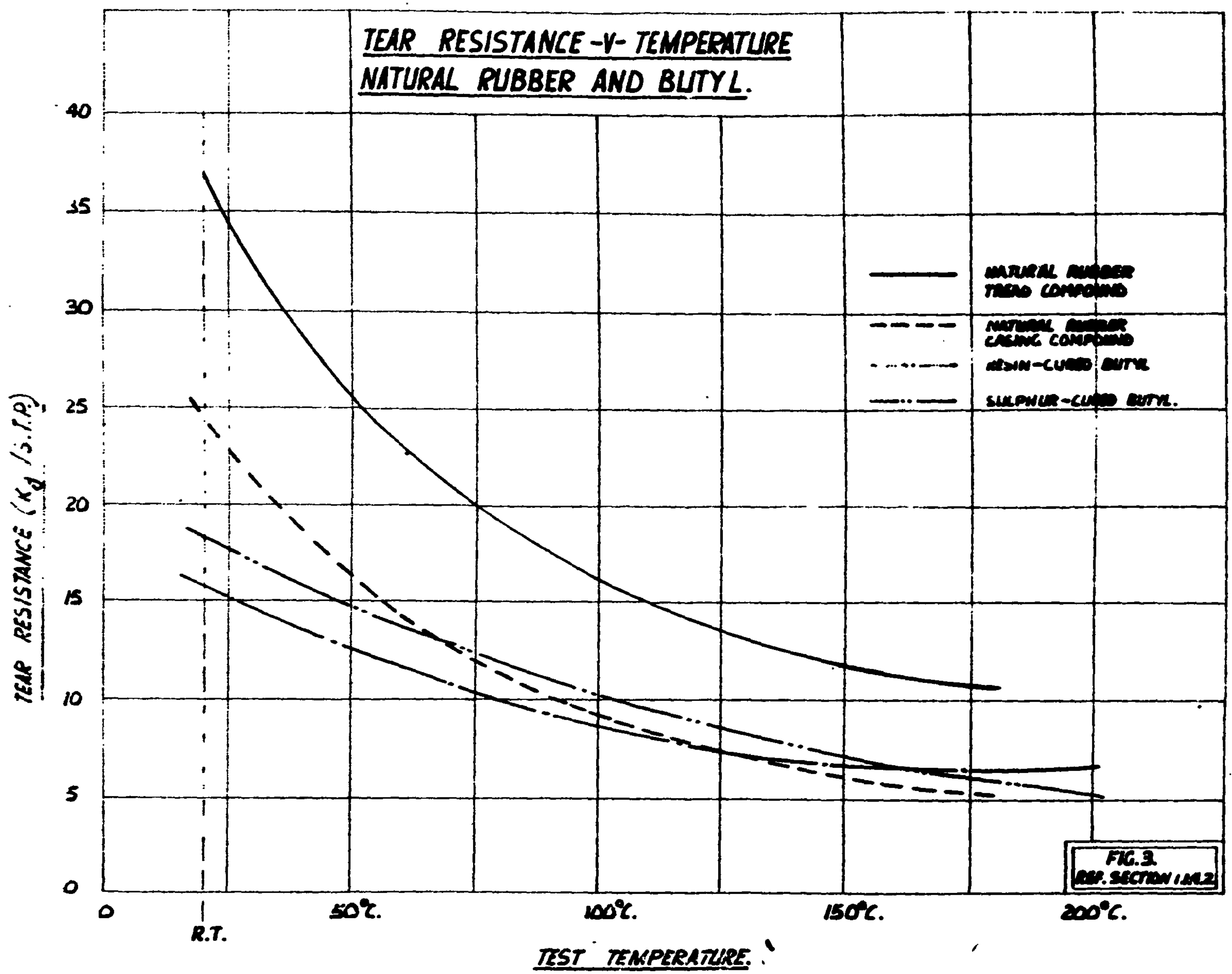


FIG. 3.
REF. SECTION 1.10.2

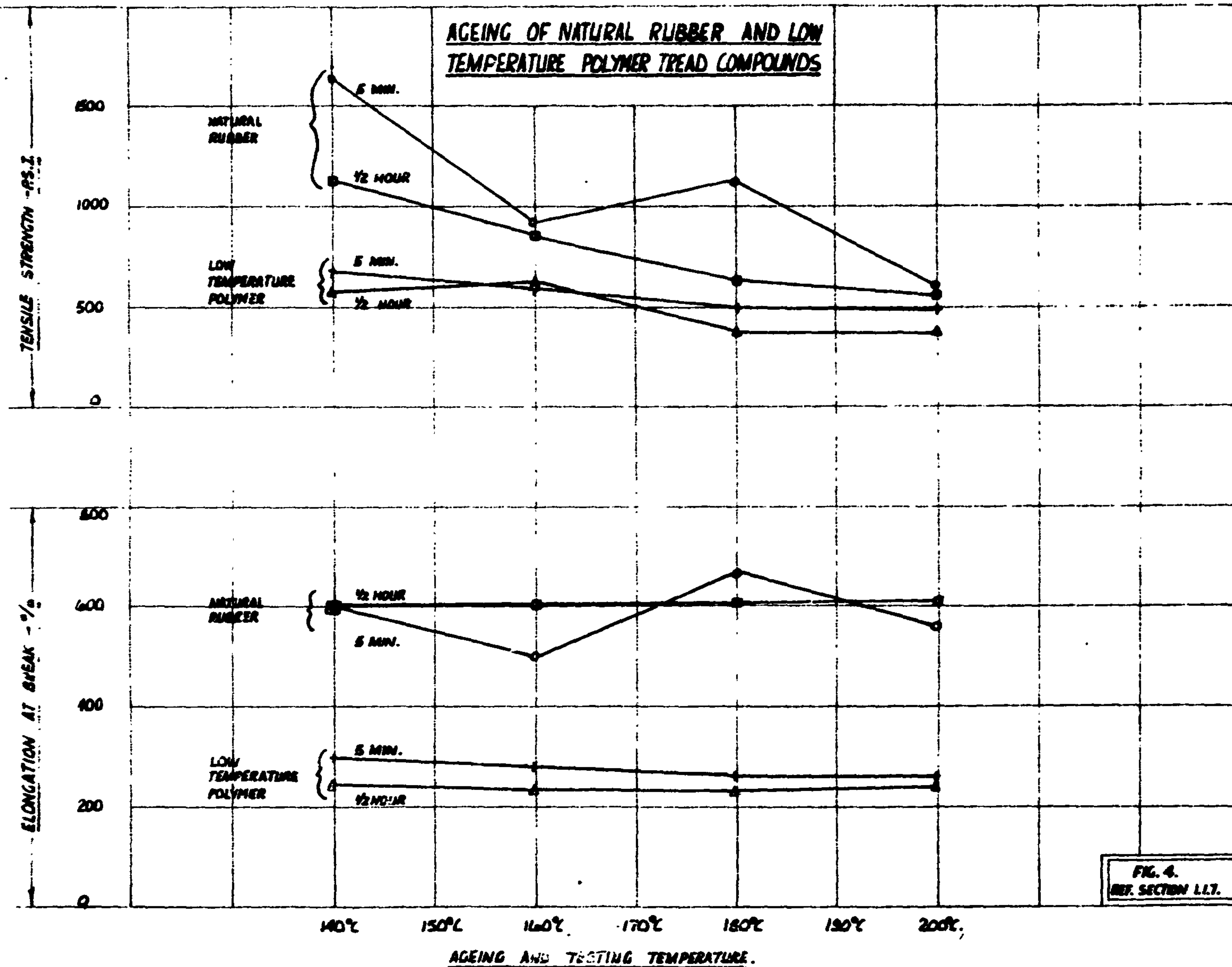
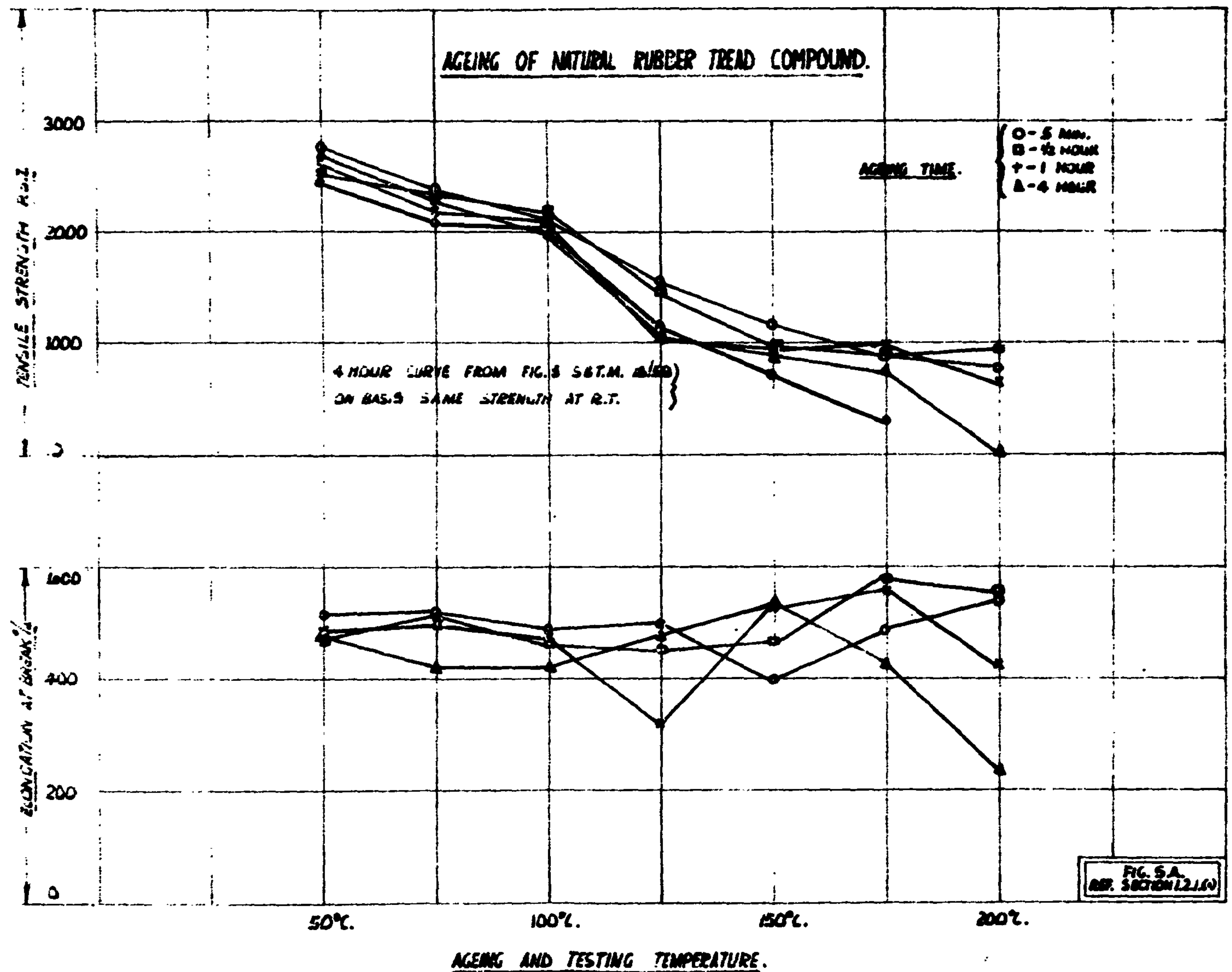
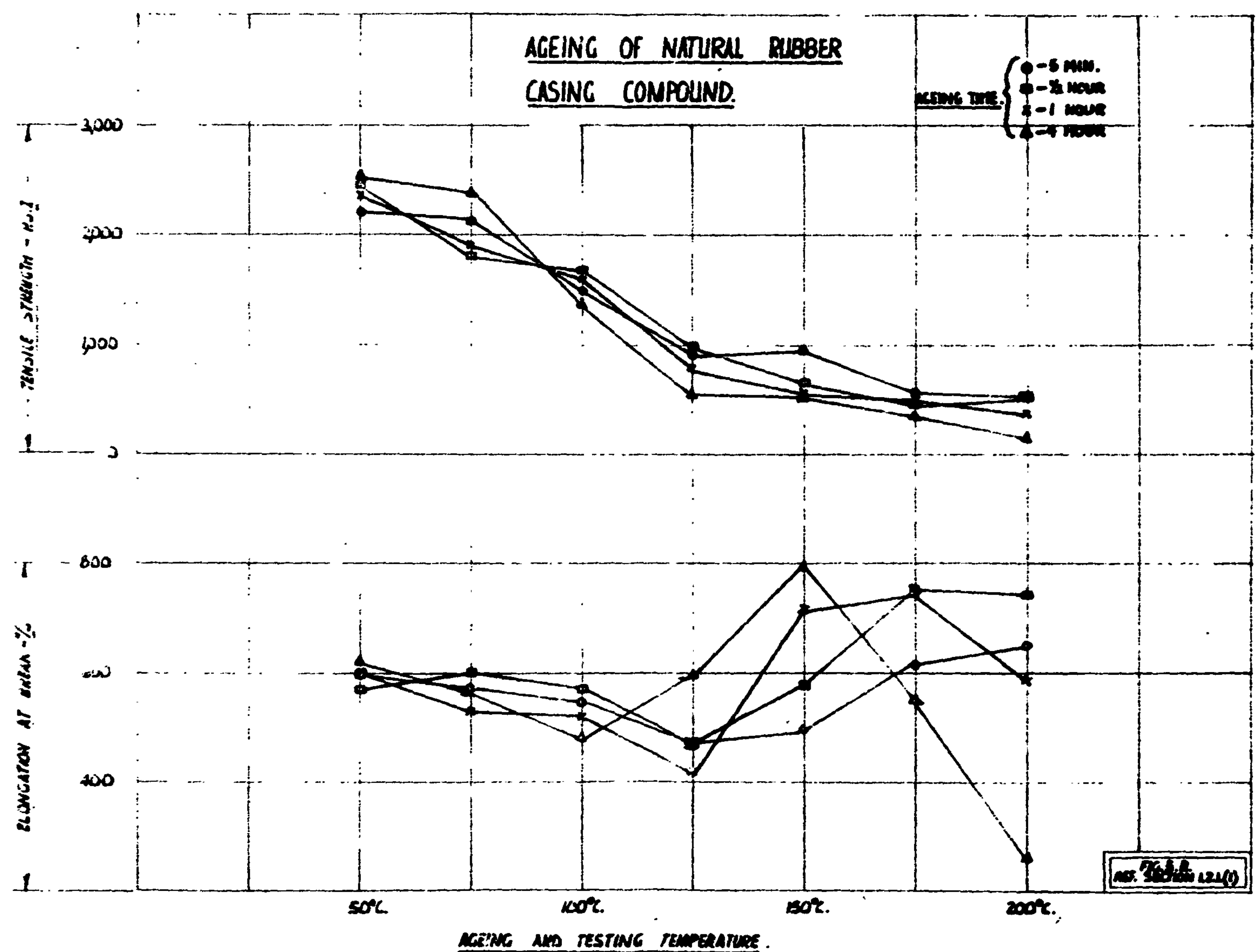


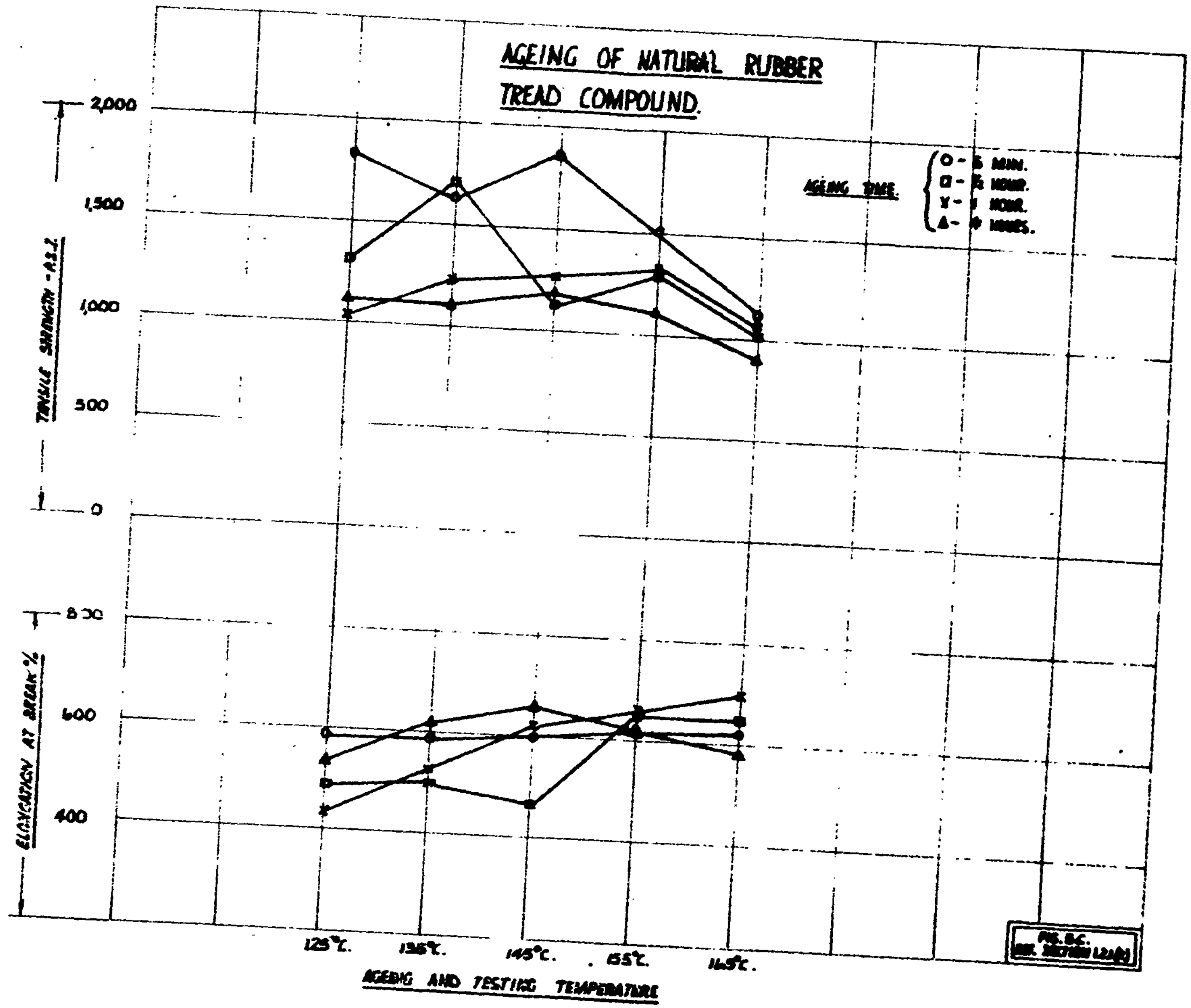
FIG. 4.
REF. SECTION I.I.T.



AGEING OF NATURAL RUBBER TREAD COMPOUND.
TENSILE STRENGTH P.S.I.
3000
2000
1000
0
AGEING TIME.
O - 5 MIN.
B - ½ HOUR
+ - 1 HOUR
Δ - 4 HOUR
4 HOUR CURVE FROM FIG. 3 SET.M. A/ED)
ON BASIS SAME STRENGTH AT R.T.
ELONGATION AT BREAK %
600
400
200
0
50°C.
100°C.
150°C.
200°C.
AGEING AND TESTING TEMPERATURE.
FIG. 5A.
REF. SECTION 1.2.1.(v)



AGEING OF NATURAL RUBBER
CASING COMPOUND.
AGEING TIME.
● – 5 MIN.
■ – ½ HOUR
x – 1 HOUR
▲ – 4 HOUR
TENSILE STRENGTH – P.S.I
3,000
2000
1000
0
ELONGATION AT BREAK – %
600
500
400
50°C.
100°C.
150°C.
200°C.
AGEING AND TESTING TEMPERATURE.


AGEING OF NATURAL RUBBER
TREAD COMPOUND.
TENSILE STRENGTH - P.S.I.
2,000
1,500
1,000
500
0
ELONGATION AT BREAK %
800
600
400
AGEING TIME.
125°C.
135°C.
145°C.
155°C.
165°C.
AGEING AND TESTING TEMPERATURE

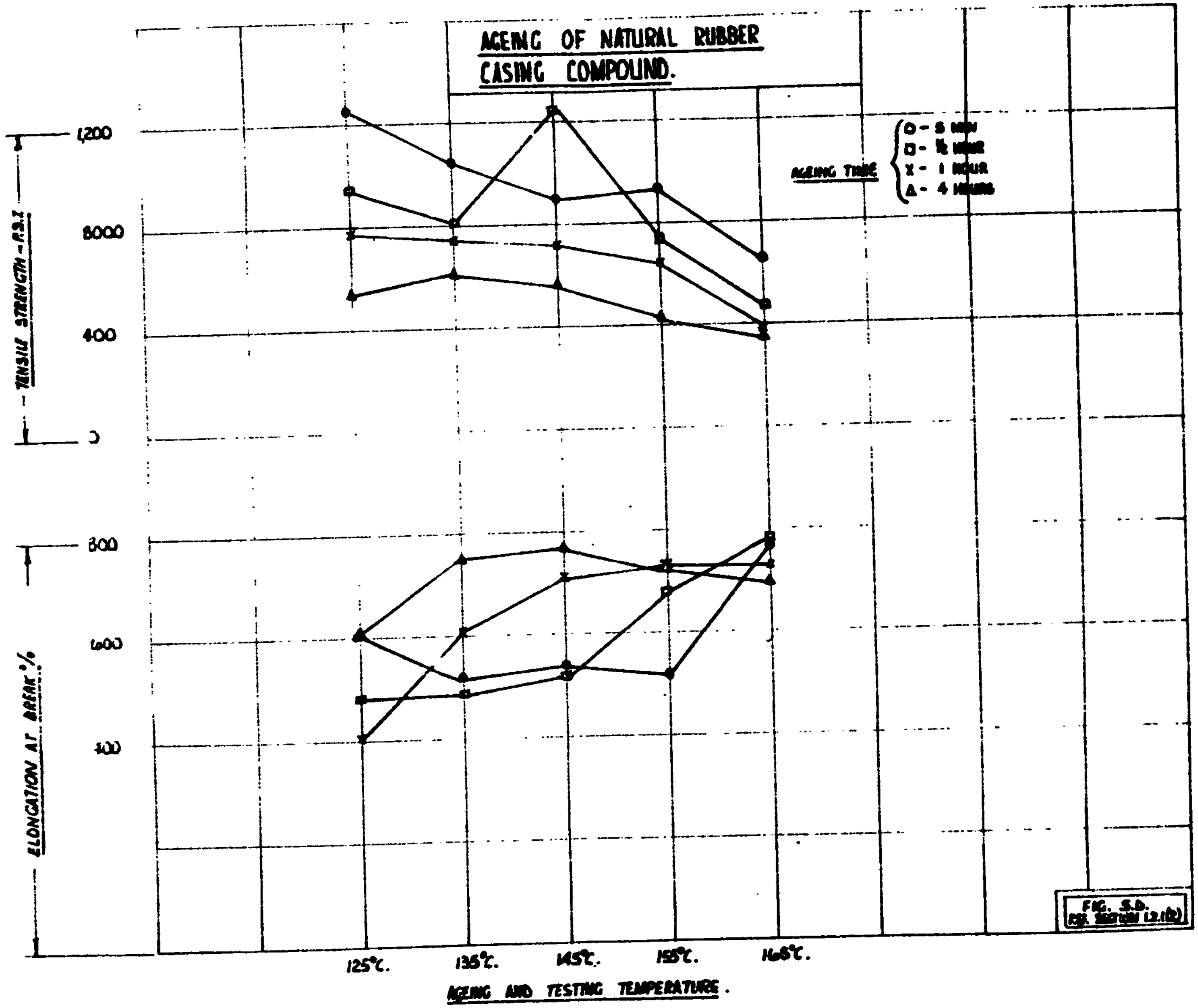


FIG. 5.D.
REF. SECTION 12.1(2)

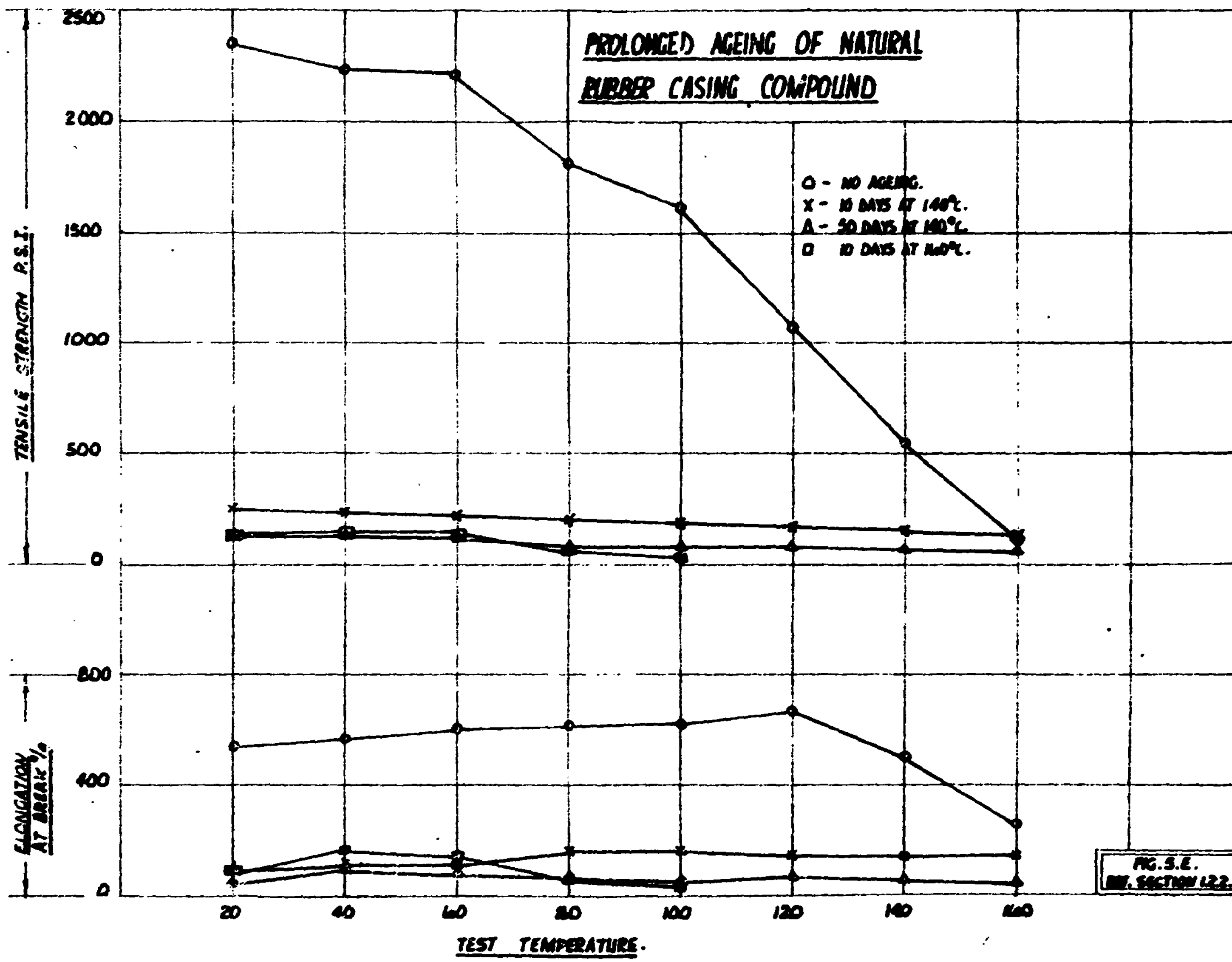
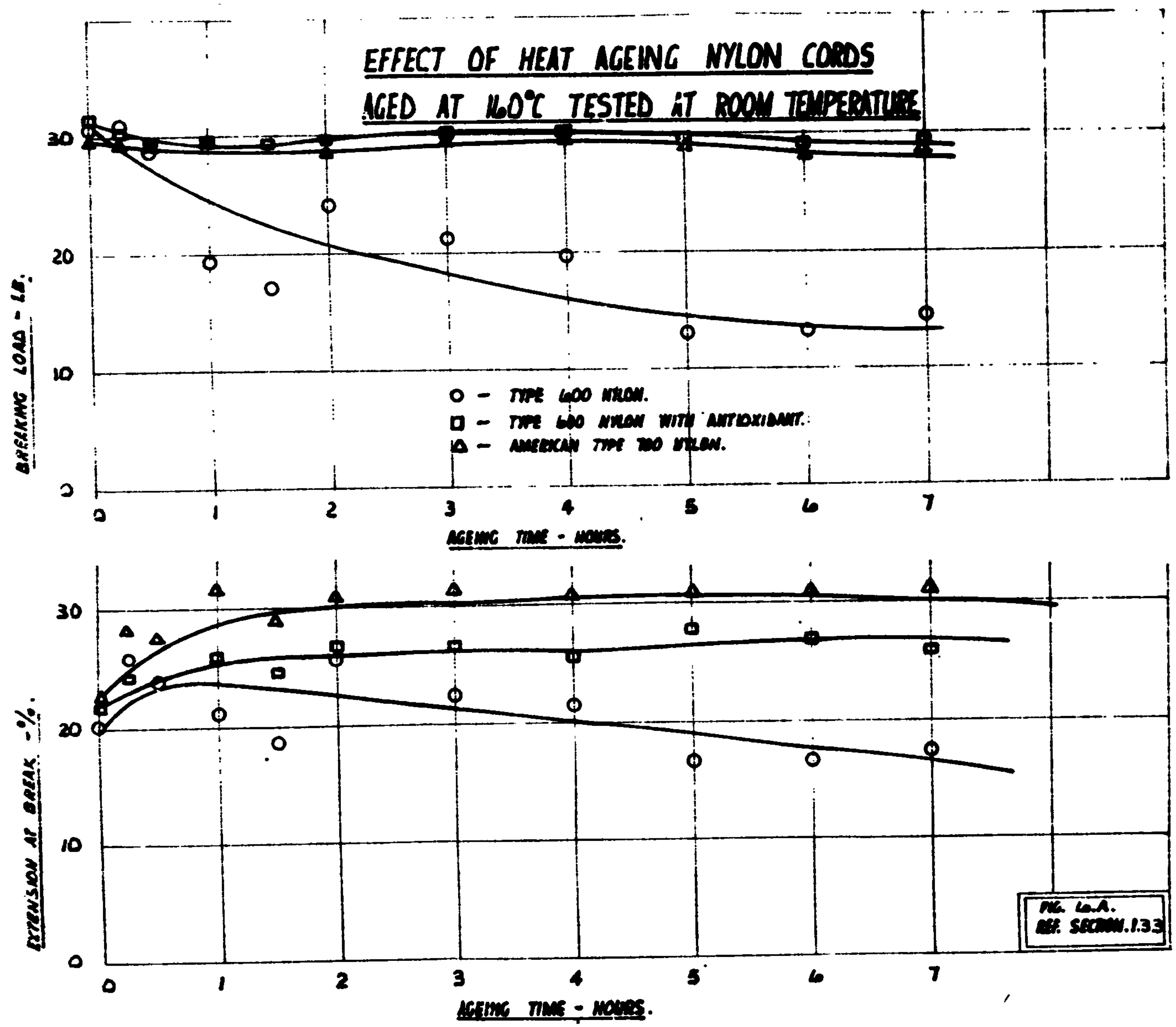


FIG. 5.E.
REF. SECTION 4.2.2.


EFFECT OF HEAT AGEING NYLON CORDS
AGED AT 160°C TESTED AT ROOM TEMPERATURE
BREAKING LOAD - LB.
○ - TYPE 600 NYLON.
□ - TYPE 600 NYLON WITH ANTIOXIDANT.
△ - AMERICAN TYPE 700 NYLON.
AGEING TIME - HOURS.
EXTENSION AT BREAK - %.
AGEING TIME - HOURS.
FIG. 6.A.
REF. SECTION.1.33

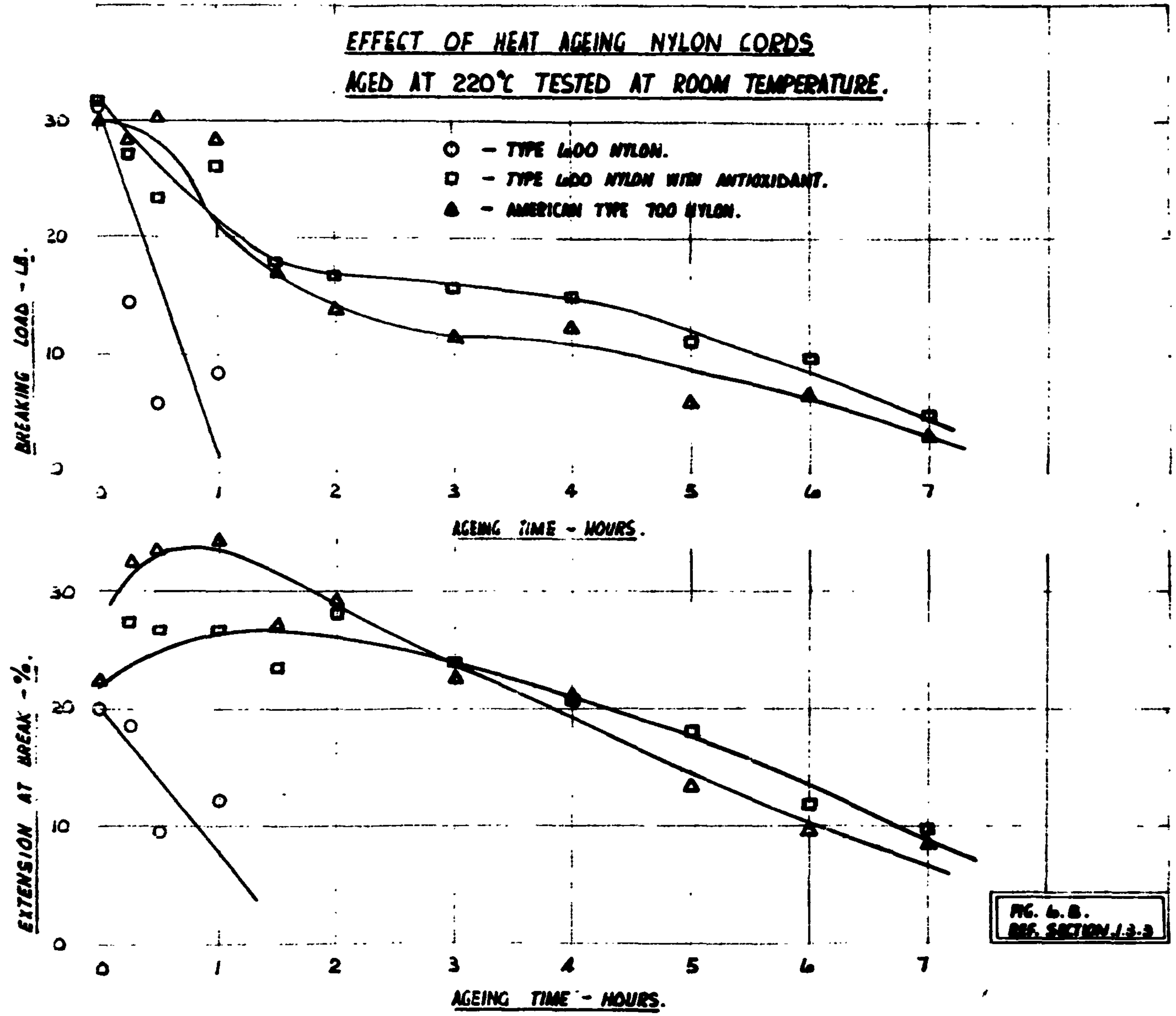


FIG. 6.B.
REF. SECTION 1.3.3

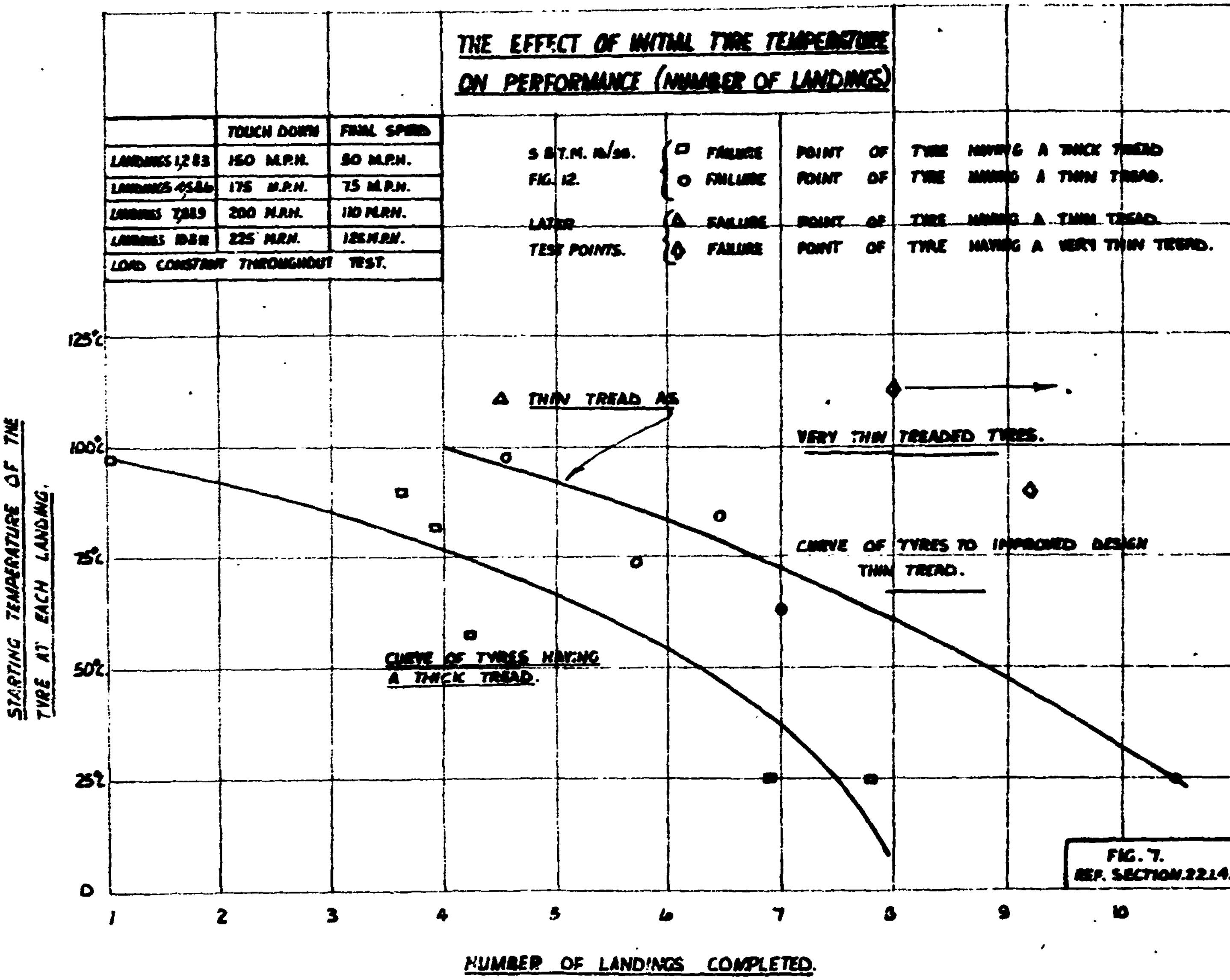


FIG. 7.
REF. SECTION 2.2.1.4.

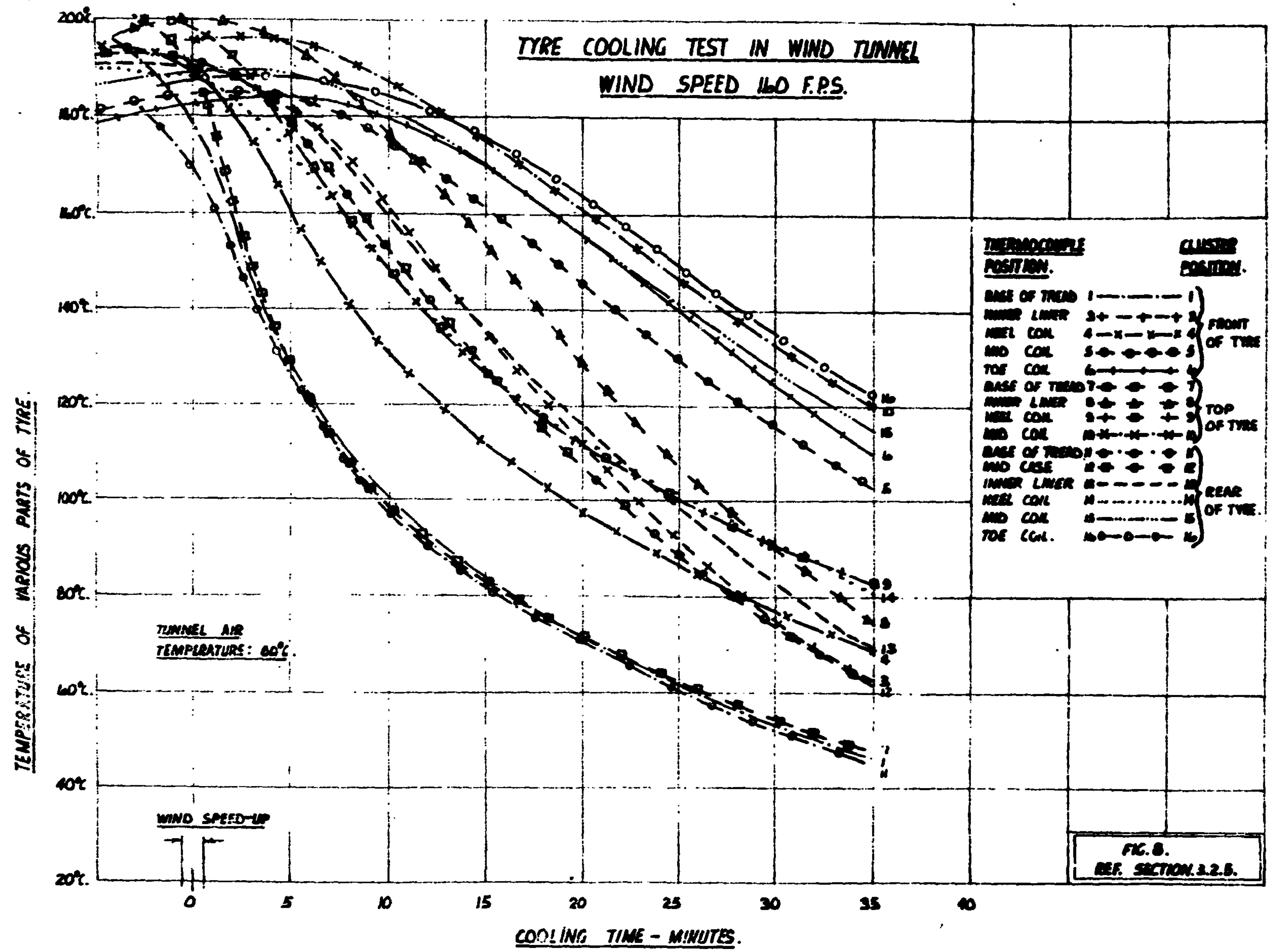


FIG. 8.
REF. SECTION 3.2.5.

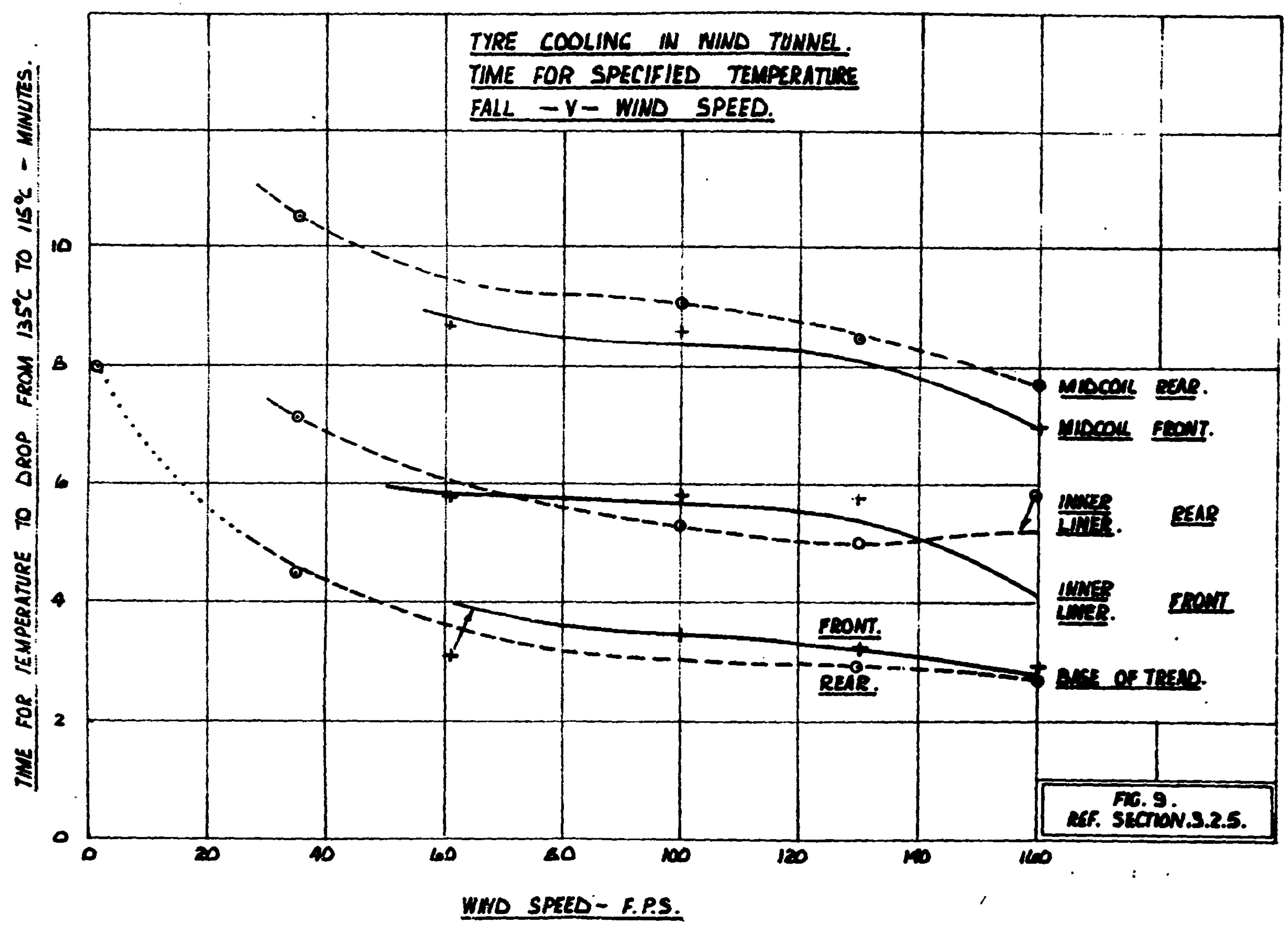


FIG. 9.
REF. SECTION.3.2.5.

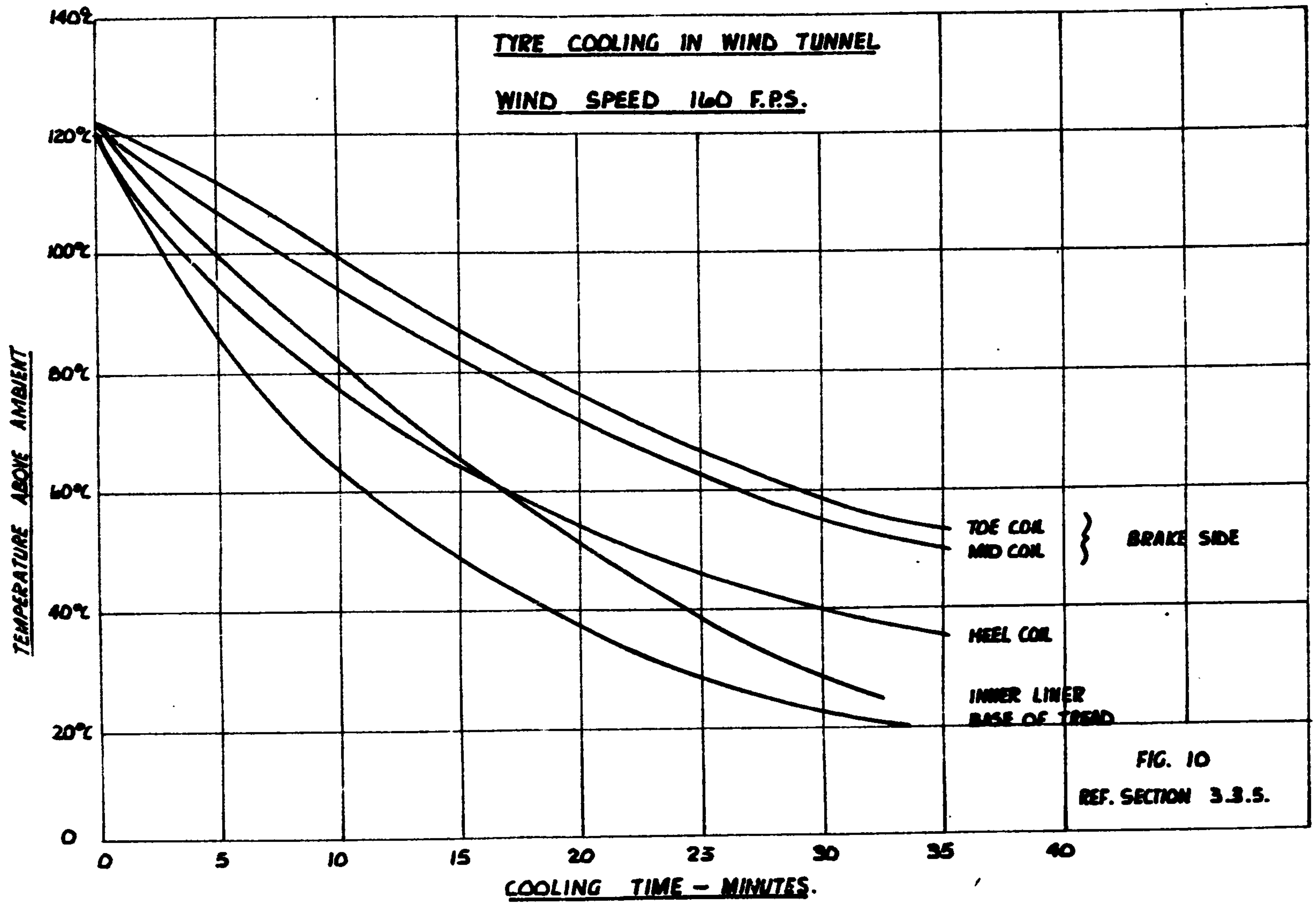


FIG. 10

REF. SECTION 3.3.5.

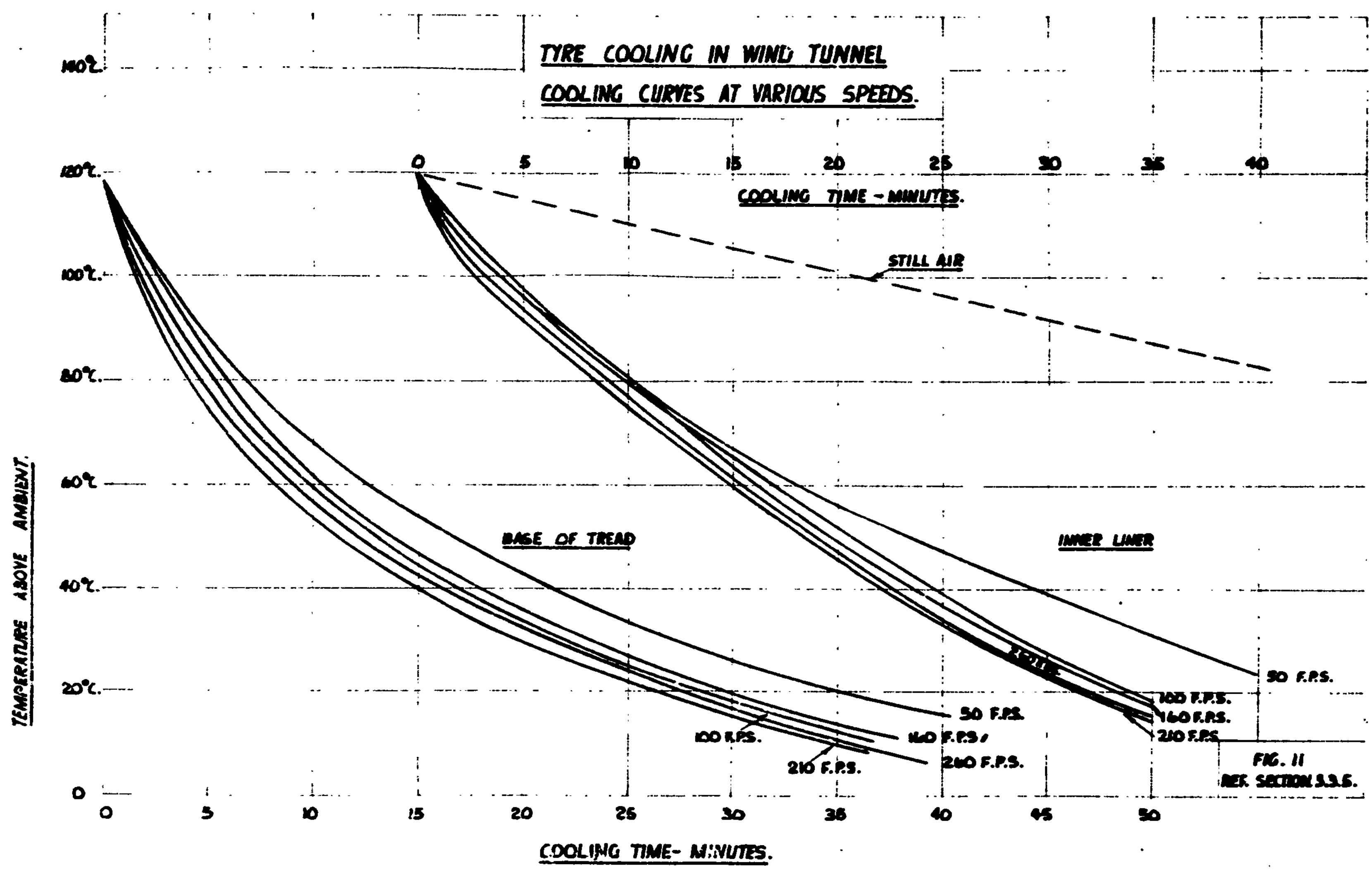


FIG. 11
REF. SECTION 3.3.6.

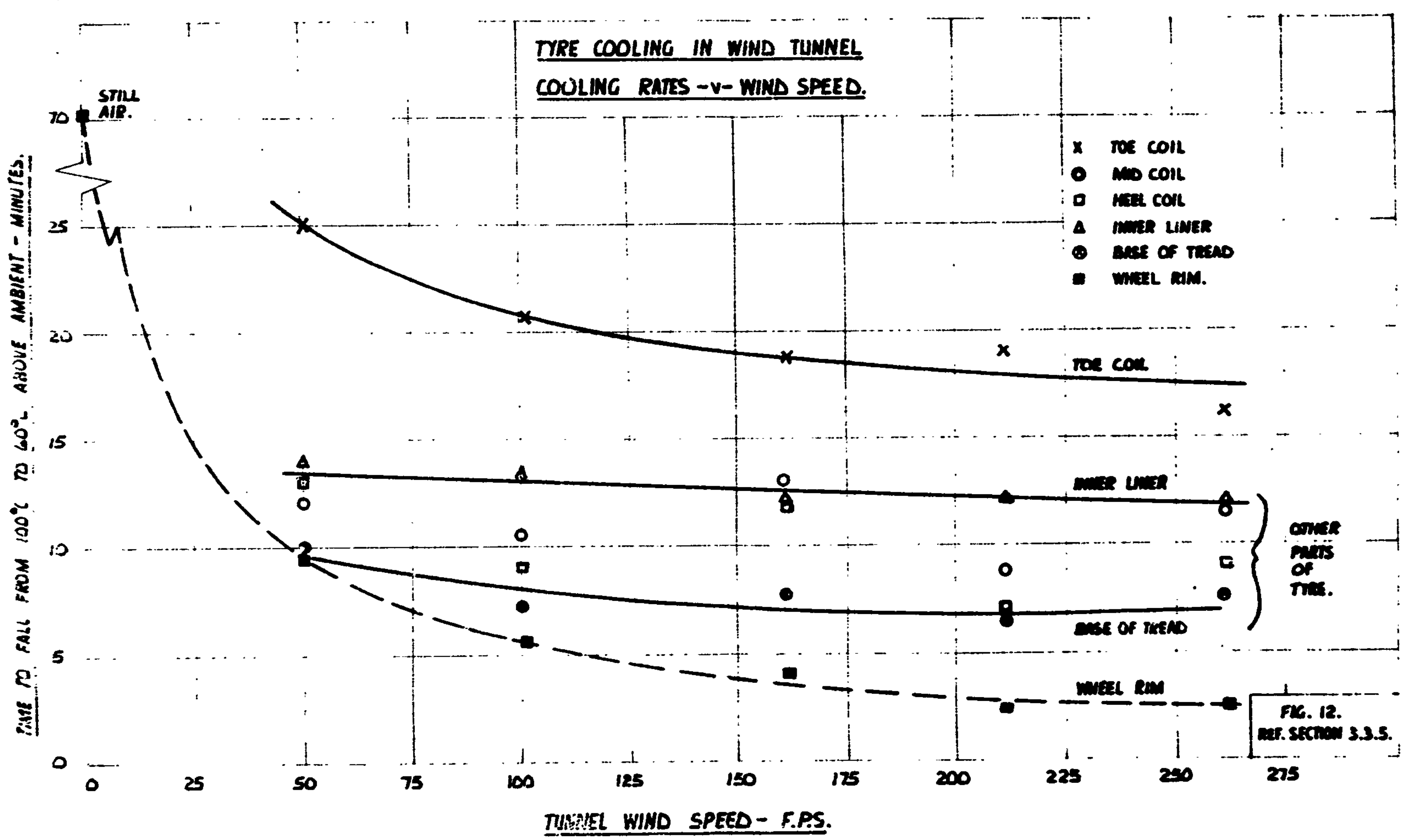


FIG. 12.
REF. SECTION 3.3.5.

S & T Memo 13/62 CONFIDENTIAL

Min.Aviat.Tech.Inf.& Liby.
Services, U.K.

629.13.015.125:
678.074:
66.018.4:
620.193.5
MOA/6/Stores/38161/CB.20(a)

INVESTIGATION OF THE HEAT RESISTANCE OF AIRCRAFT TYRES AND COMPONENT MATERIALS (REPORT OF WORK CARRIED OUT BY DUNLOP RUBBER CO.LTD.)

Feb.,1963 29pp.,12fig.,

(i) Laboratory determination of the effect of heat on the tensile properties of heat resistant synthetic elastomers, natural rubbers and nylon cords were continued. (ii) Further tyre heating tests were made using the infra-red heating chamber to confirm and extend the results from earlier work on standard construction tyres to tyres with thin treads and to tyres with nylon cords and steel cords. (iii) Tests were made in a wind tunnel using a preheated tyre to determine the rate of cooling of wheels and tyres when subjected to a cooling wind at various speeds, as when extended into the slipstream before the landing run. (iv) Work was continued on the construction of special heat resistant tyres using steel cores and heat resisting polymers.

S & T Memo 13/62 CONFIDENTIAL

Min.Aviat.,Tech.Inf.& Liby.
Services, U.K.

629.13.015.125:
678.074:
66.018.4:
620.193.5
MOA/6/Stores/38161/CB.20(a)

INVESTIGATION OF THE HEAT RESISTANCE OF AIRCRAFT TYRES AND COMPONENT MATERIALS (REPORT OF WORK CARRIED OUT BY DUNLOP RUBBER CO.LTD.)

Feb.,1963 29pp.,12fig.,

(i) Laboratory determination of the effect of heat on the tensil properties of heat resistant synthetic elastomers, natural rubbers and nylon cords were continued. (ii) Further tyre heating tests were made using the infra-red heating chamber to confirm and extend the results from earlier work on standard construction tyres to tyres with thin treads and to tyres with nylon cords and steel cords. (iii) Tests were made in a wind tunnel using a preheated tyre to determine the rate of cooling of wheels and tyres when subjected to a cooling wind at various speeds, as when extended into the slipstream before the landing run. (iv) Work was continued on the construction of special heat resistant tyres using steel cords and heat resisting polymers.

S & T Memo 13/62 CONFIDENTIAL

Min.Aviat.,Tech.Inf.& Liby.
Services, U.K.

629.13.015.125:
678.074:
66.018.4:
620.193.5
MOA/6/Stores/38161/CB20(a)

INVESTIGATION OF THE HEAT RESISTANCE OF AIRCRAFT TYRES AND COMPONENT MATERIALS (REPORT OF WORK CARRIED OUT BY DUNLOP RUBBER CO.LTD.)

Feb.,1963 29pp.,12fig.,

(i) Laboratory determination of the effect of heat on the tensil properties of heat resistant synthetic elastomers, natural rubbers and nylon cords were continued. (ii) Further tyre heating tests were made using the infra-red heating chamber to confirm and extend the results from earlier work on standard construction tyres to tyres with thin treads and to tyres with nylon cords and steel cords. (iii) Tests were made in a wind tunnel using a preheated tyre to determine the rate of cooling of wheels and tyres when subjected to a cooling wind at various speeds, as when extended into the slipstream before the landing run. (iv) Work was continued on the construction of special heat resistant tyres using steel cords and heat resisting polymers.

S & T Memo 13/62 CONFIDENTIAL

Min.Aviat.,Tech.Inf.& Liby.
Services, U.K.

629.13.015.125:
678.074:
66.018.4:
620.193.5
MOA/6/Stores/38161/CB20(a)

INVESTIGATION OF THE HEAT RESISTANCE OF AIRCRAFT TYRES AND COMPONENT MATERIALS (REPORT OF WORK CARRIED OUT BY DUNLOP RUBBER CO.LTD.)

Feb.,1963 29pp.,12fig.,

(i) Laboratory determination of the effect of heat on the tensile properties of heat resistant synthetic elastomers, natural rubbers and nylon cords were continued. (ii) Further tyre heating tests were made using the infra-red heating chamber to confirm and extend the results from earlier work on standard construction tyres to tyres with thin treads and to tyres with nylon cords and steel cords. (iii) Tests were made in a wind tunnel using a preheated tyre to determine the rate of cooling of wheels and tyres when subjected to a cooling wind at various speeds, as when extended into the slipstream before the landing run. (iv) Work was continued on the construction of special heat resistant tyres using steel cords and heat resisting polymers.

dstl

Information Centre
Knowledge Services
[dstl] Porton Down,
Salisbury
Wilts
SP4 0JQ
22060-6218
Tel: 01980-613753
Fax 01980-613970

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: AD337255

Date of Search: 17 November 2008

Record Summary: AVIA 10/433
Title: Investigation of the heat resistance of aircraft tyres and component materials, conducted by Dunlop Rubber Company Ltd
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) 13/62
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as UNLIMITED.